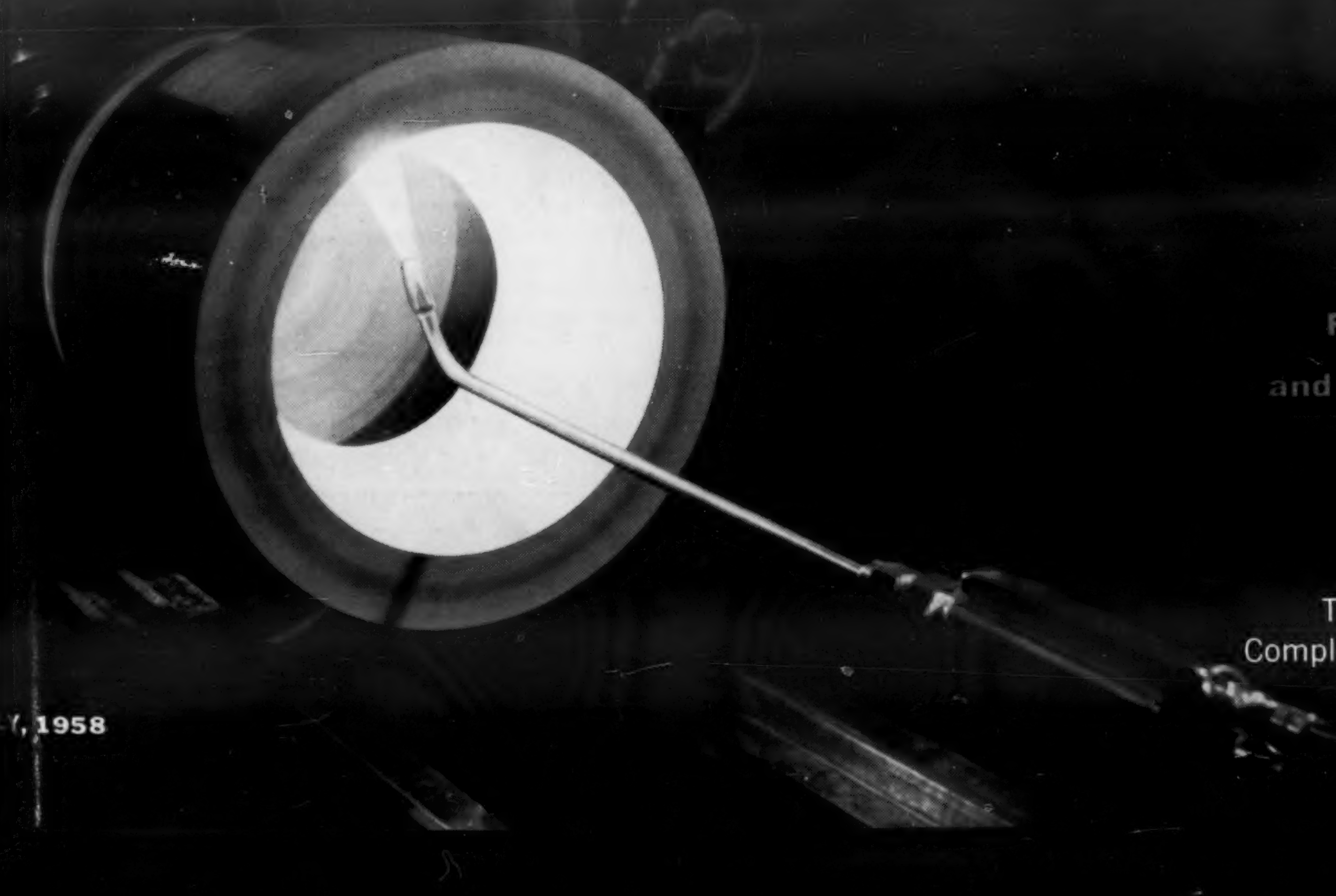
Materials in Design Engineering

FORMERLY
MATERIALS
& METHODS

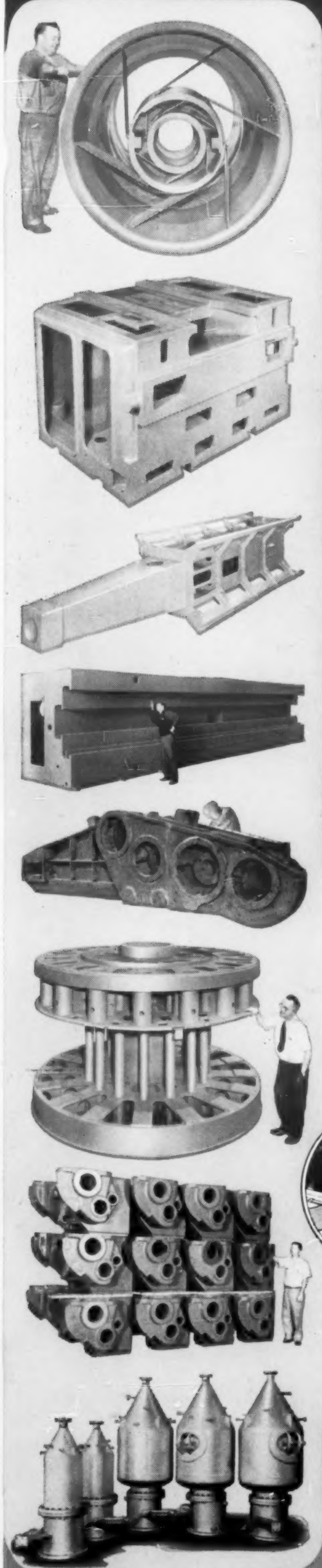
SELECTION & USE OF METALS, NONMETALLICS, FORMS, FINISHES



Porcelain Enamels
and Ceramic Coatings
Manual No. 150

Also:
High Strength Steels
The New Polyethylenes
Complete Contents—page 1

Y, 1958



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PUBLISHED BY
REINHOLD PUBLISHING CORP.
430 PARK AVE., NEW YORK 22, N. Y.

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Materials in Design Engineering
formerly Materials & Methods

Selection & use of metals, nonmetallics, forms, finishes

JULY 1958
VOL. 48, NO. 1

FEATURES

DEPARTMENTS

COVER BY HARRY & MARION ZELENKO; PHOTO COURTESY CONTINENTAL COATINGS CORP.

Drilling mud, containing sand and rock particles, looks like this as it flows from a well hole. It is "freshened up" for re-use in a cleaning machine equipped with a wear-resisting Monel alloy screen. *Photo courtesy Standard Oil Company, (New Jersey).*

What's new IN MATERIAL

...AT A GLANCE

ELIMINATION OF STRESS CORROSION CRACKING IN BRONZE PARTS is said to result from use of a new aluminum bronze alloy. The alloy is also said to maintain a high degree of strength and corrosion resistance at temperatures up to 500 F. According to the developer, it is the addition of 0.35% tin to the analysis that prevents stress corrosion cracking. (More details next month.)

LUBRICANTS FOR USE UP TO 1000 F may come out of the development of a new class of materials called perarylated silanes. Research shows a perarylated silane lubricant is thermally stable at 1000 F, is inert to most chemicals, and has electrical properties similar to those of polystyrene. One drawback: the lubricant is not liquid until it reaches a temperature of 200 F.

FASTER, MORE EFFECTIVE CURING SYSTEMS FOR RUBBER AND PLASTICS may be realized by using a newly developed series of latent curing aids. The curing aids are said to permit the use of highly active compounds to obtain fast cures, while providing increased processing safety and pot life. The aids may be used in styrene-butadiene rubber, natural rubber, neoprene, nitrile rubber, epoxy resins and rigid vinyl plastisols.

ALUMINUM-URANIUM ALLOYS SHOW PROMISE AS REACTOR FUELS for low temperature, water cooled reactors, according to recent research. A study indicates that aluminum alloys with relatively high uranium contents have good corrosion resistance in water up to 300 F and have good thermal conductivity. In addition, the alloys can be easily fabricated at temperatures below 1000 F.

LOWER COST POLYETHYLENE PARTS may result from the development of two improved plastics forming techniques. One technique, slush molding, is said to provide good control of polyethylene mold and machine costs and produce detailed, high quality end products. The other technique, air-slip or "bubble gum" plastics forming, is said to produce polyethylene parts with

more uniform wall thickness than any other thermoforming method. The developer says the technique eliminates the need to design thick walls near the bottom of a mold to obtain a given thickness near the top.

ANOTHER HIGHLY TRANSPARENT MEDIUM DENSITY POLYETHYLENE FILM shows promise as a packaging material. Not yet commercially available, the film is reported to have a haze rating of 3%. It is produced by strip extrusion and quenching.

FASTER BARREL FINISHING OF COMPLEX-SHAPED PARTS can be accomplished by using a new method that is said to slash finishing time cycles by as much as 70%. The method, in addition to speeding up time cycles, also finishes the inside diameters of parts. The finishing system operates by combining the principles of rotation and vibration which set up opposing forces within the barrel.

POLYPROPYLENE RUBBER WITH HIGHER STRENGTH THAN NATURAL RUBBER is reportedly being road tested in Italian tires. The elastomer, a copolymer of propylene and ethylene, is still in the experimental stage. It seems to be compatible for blending with natural rubber and a variety of synthetic rubbers.

DUCTILE MOLYBDENUM THAT CAN BE ROLLED AND EXTRUDED has come out of the development of a new process that eliminates such impurities in the metal as oxygen, carbon, nitrogen and hydrogen. The metal, recommended for high speed aircraft and guided missile parts, can also be fabricated by powder metallurgy techniques. According to the developers, the ductile molybdenum has outstanding strength properties at high temperatures.

A COATING THAT ALLOWS AIRCRAFT TO ESCAPE RADAR DETECTION has been developed by U. S. Air Force scientists. The Air Force has not revealed what the coating is, but some observers believe it contains materials that cause wave loss through absorption; such materials are rubber bonded to ceramics and horse hair impregnated with carbon.

ULTRA-THIN ZIRCONIUM AND TITANIUM FOIL is now available in production lot quantities. The zirconium foil is available in thicknesses as low as 0.0008 in., whereas the titanium foil is available in thicknesses as low as 0.0003 in.

Turn to page 125 for more "What's New in Materials"

MATERIALS BRIEFS

Corrosion Resistant Flamingos?

Flamingos are coming north of the Mason-Dixon line as cast aluminum shapes finished in brilliant pink with red, black and white markings. The birds, intended as lawn decorations, are mounted on wrought iron legs.

One for the Records

A box for storing valuable records consists of a ductile iron compartment covered with silicone foam and encased in a stainless steel shell. The shell is coated with a paint that foams into a fire resistant coating when the surrounding temperature reaches 300 F.

Improved by Damaging

Strength, hardness and electrical resistance of stainless steel, nickel, titanium, copper and iron can be improved by damaging them with nuclear reactor radiation, according to recent research.

Modern Roof for a Castle

Manufactured aluminum batten roll roofing is replacing handmade lead, copper and zinc roofing on an ancient castle in England. Aluminum roofing is said to do the same job at lower cost, and yet look just as attractive as the old handmade roofing.

Chemical Conserves Water

A chemical film of hexadecanol has reduced water evaporation in U. S. and Australian reservoirs by as much as 50 to 65%. The chemical forms a thin film on the surface of the water and seals it off from the air.

MATERIALS AT WORK

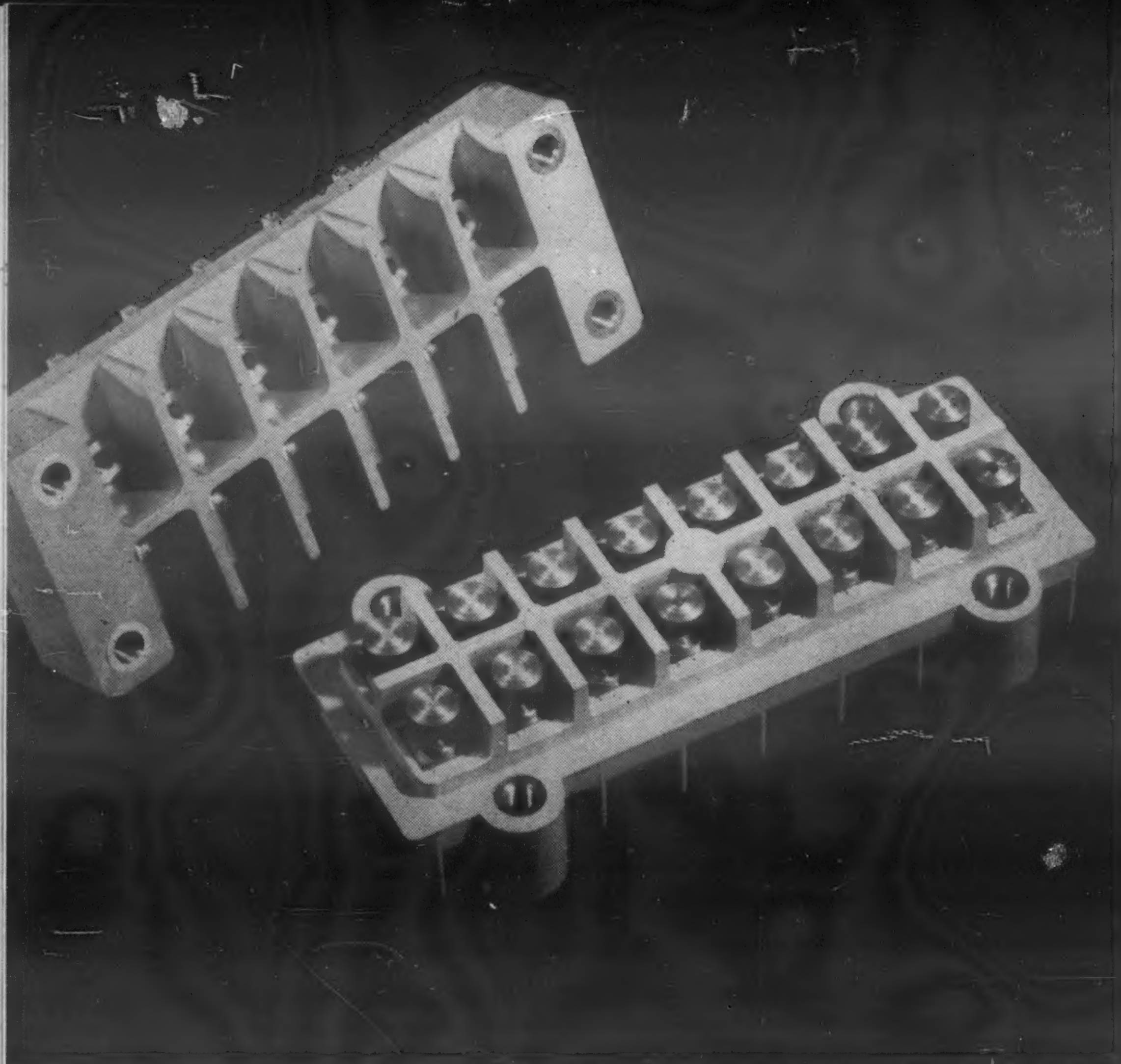
New and interesting applications of engineering materials

Aluminum Co. of America

Aluminum trims auto weight

Light weight, ease of fabrication and attractive appearance are the reasons given for the "steadily increasing" use of aluminum in new automobiles for such things as trim, automatic transmission assemblies, power brakes and steering mechanisms (see top photo).

An innovation is Buick's use of one of the longest extruded trim panels which sweeps from tail light to a midpoint in the rear door (see bottom photo).



Barrett Div., Allied Chemical Corp.

Alkyd terminal boards have molded-in inserts

The intricate terminal boards shown in the accompanying photo are molded of alkyd plastic and are used in electrical heaters in the new Lockheed Electro turboprop airliner.

Alkyd was chosen because of its good strength and electrical resistance and because its excellent molding properties permit a large number of molded-in inserts and wide variations in cross section (including thin barrier webs and heavy sections around the inserts).

Stainless steel aerosol dispenses medicines

Excellent resistance to corrosion, good strength and ease of cleaning are the reasons given for the selection of type 305 stainless steel for what are believed to be the first metal aerosol bottles (see photo at right) used to dispense medicines and drugs.

The bottles, 13/16 in. in dia and 2½ in. long, are formed from 3-in. blanks in six draws. According to Tubing Seal Cap, Inc., the new medicine bottles are completely free of pits, holes and cracks, and have two primary advantages over glass bottles previously used: 1) they are unbreakable, and 2) they protect active drugs from light and air.

Allegheny Ludlum Steel Corp.

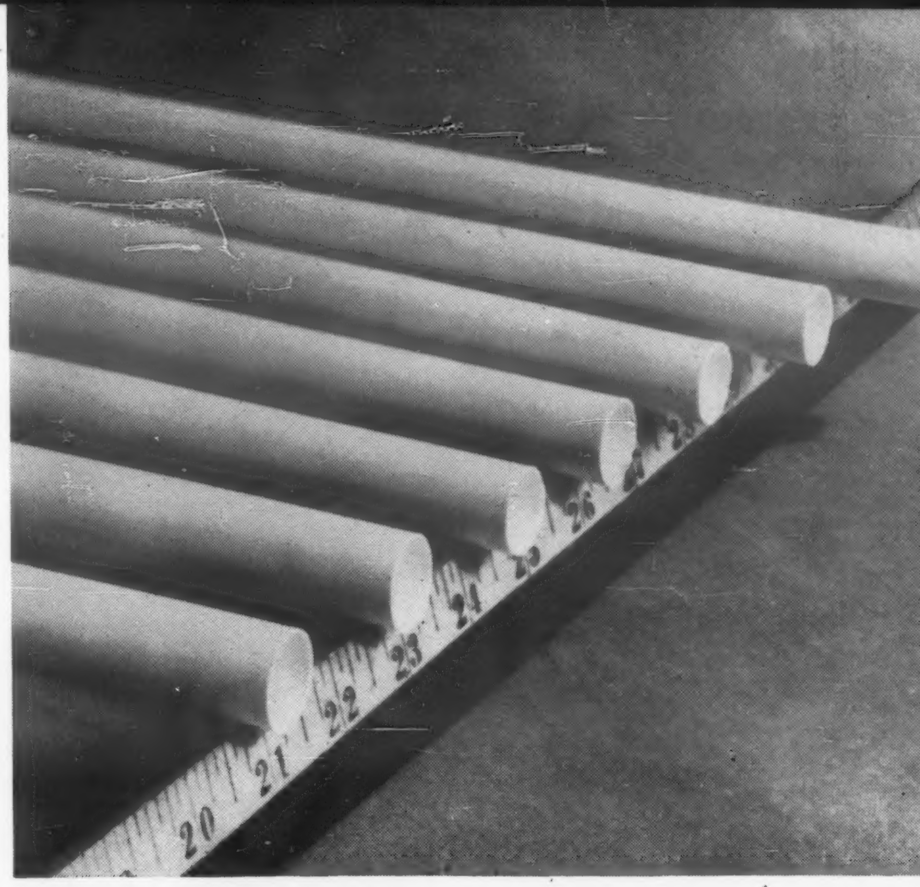
Pyroceram useful as...

Shown on this page are some of the first parts made of Corning Glass Works' new "glass-ceramic" material.

According to Corning, the material has potential value for such things as bearing parts in high temperature equipment, piston heads, precision-made aircraft structural parts, architectural curtain walls, guided missile nose cones and high temperature tubing for heat exchangers.

The advantages offered by Pyroceram for such uses are: 1) extremely low coefficient of thermal expansion up to 1800 F, 2) exceptional hardness, 3) three times the mechanical strength of ordinary glass, and 4) ability to be formed by any high speed glass manufacturing method.

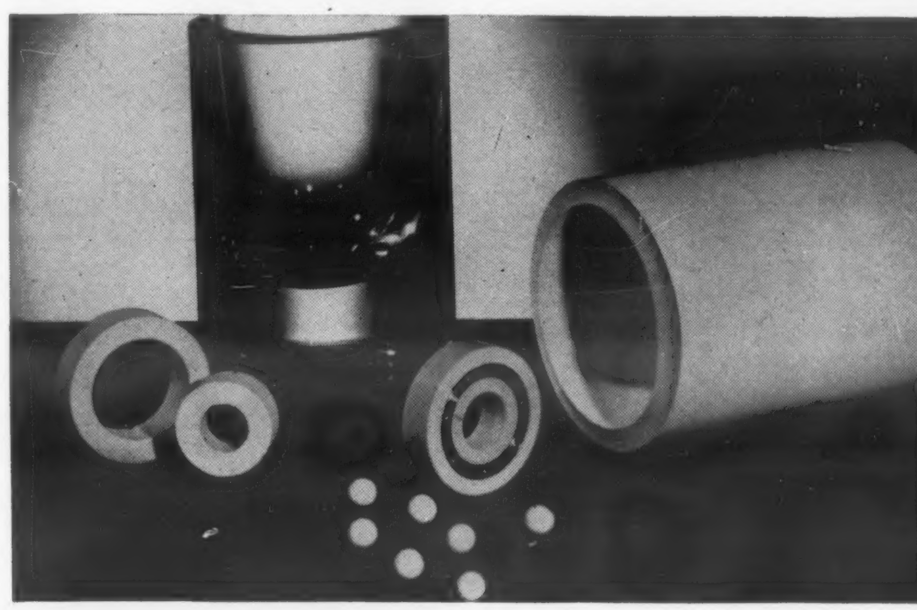
For further technical information, see MATERIALS IN DESIGN ENGINEERING, July '57, p 142.



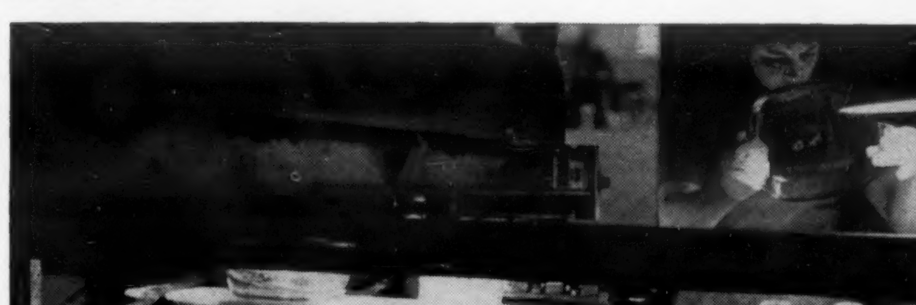
High temperature tubing

Blown ware

Ball bearing parts and pistons



Pressed ware

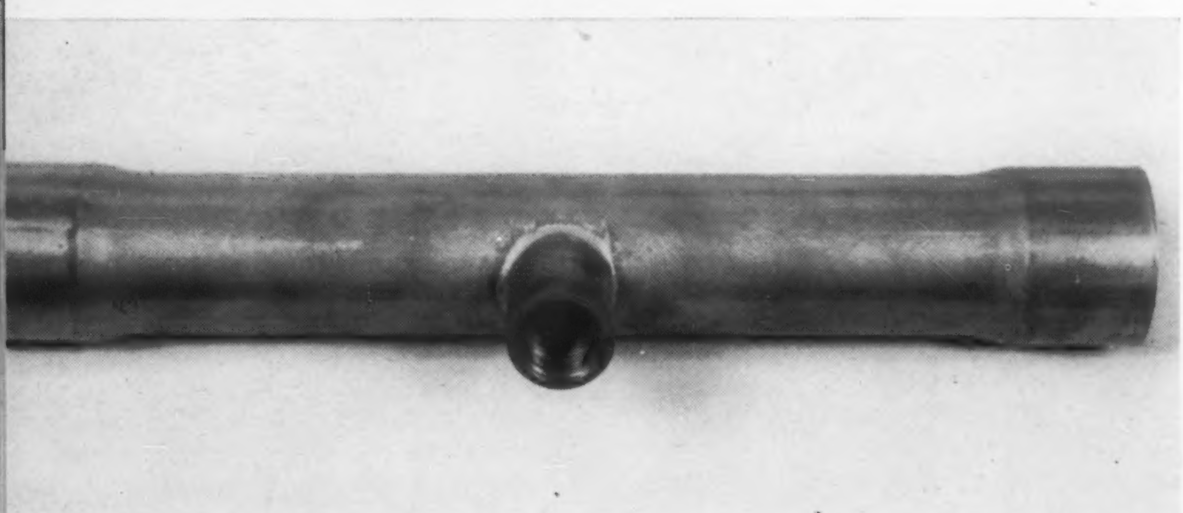


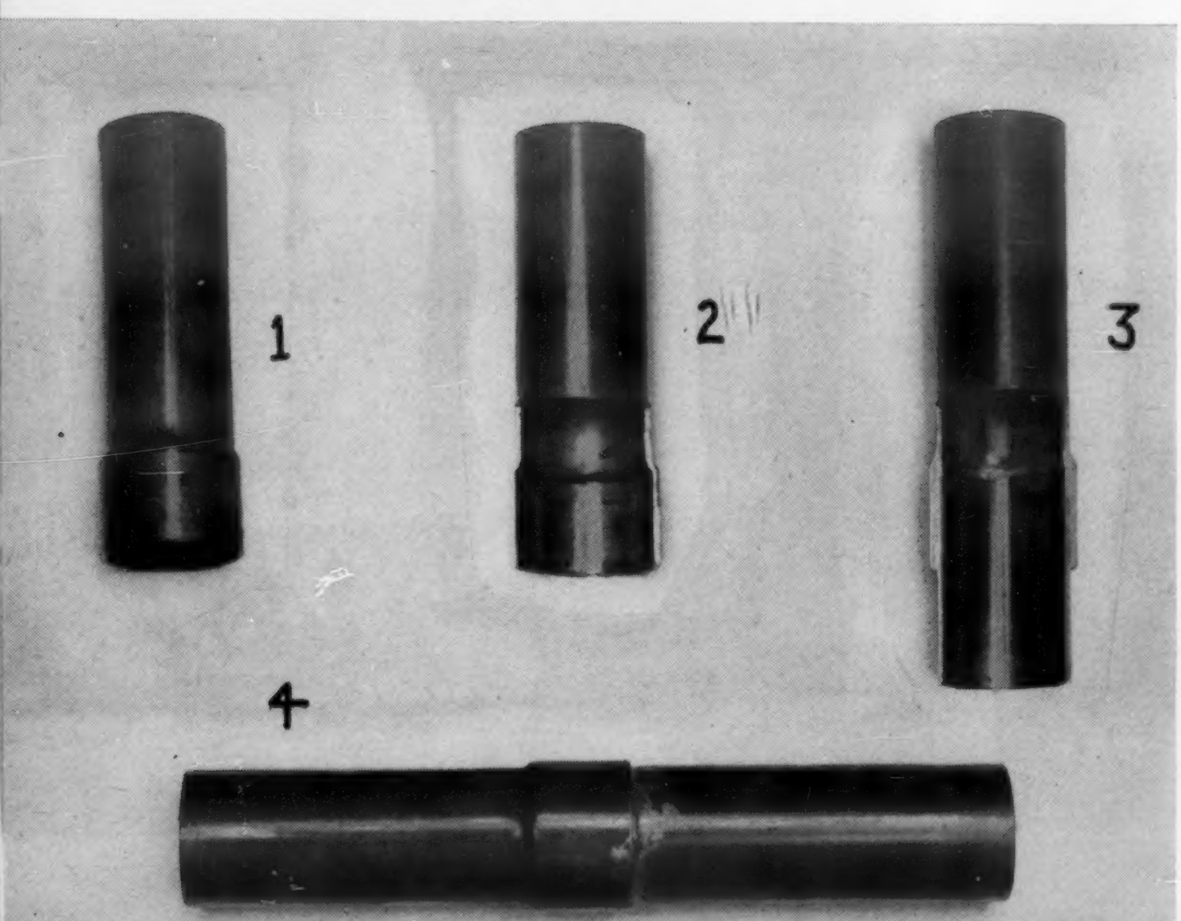
Installed piping *occupies a minimum of space.*

Silver-brazed joints for lightweight steel pipe

Twenty-five miles of lightweight steel piping utilizing silver-brazed malleable iron fittings have solved the problem of providing separate lines for each of the many paint colors necessary for automobile finishes. As specified by Ford Motor Co., each paint line had to: 1) allow smooth, even flow of the viscous paint, 2) have leakproof joints, 3) be easy to clean, 4) have a minimum pressure drop, 5) bend easily around obstructions, and 6) be accessible for maintenance.

According to Standard Tube Co., silver-brazed Smoothweld steel pipe satisfied all requirements. The joints are easily made by applying heat to *(continued on p 152)*





Outlets from line *(left) are easily made by brazing threaded pipe into hole cut in fitting. Photo at lower left shows details of braze: 1) expanded end cup; 2) cross section of expanded end cup; 3) cross section of completed silver-brazed joint; and 4) completed joint.*

MORE MATERIALS AT WORK

For more information, turn to Reader Service card, circle No. 367

Submitting articles to M/DE

To the Editor:

The Structures and Mechanics Laboratory is engaged in research which affords information of the type published in your magazine; consequently, research personnel may desire to submit articles for your consideration.

For the convenience of these personnel, it is requested that copies of your editorial standards or instructions for preparation of manuscripts be forwarded for reference.

W. A. MRAZEK
Director, Structures & Mechanics Lab
Development Operations Div.
Redstone Arsenal, Ala.

To the Editor:

I am interested in submitting a technical article for publication in M/DE. Please let me know the requirements for manuscripts, figures, tables and photographs.

GILBERT P. SOLLOTT
Chemist, Pitman-Dunn Laboratories
Frankford Arsenal
Philadelphia 37, Pa.

Pamphlets detailing our editorial needs and other information for authors have been prepared in response to such letters as these and are now available upon request.

Thermal insulation error

To the Editor:

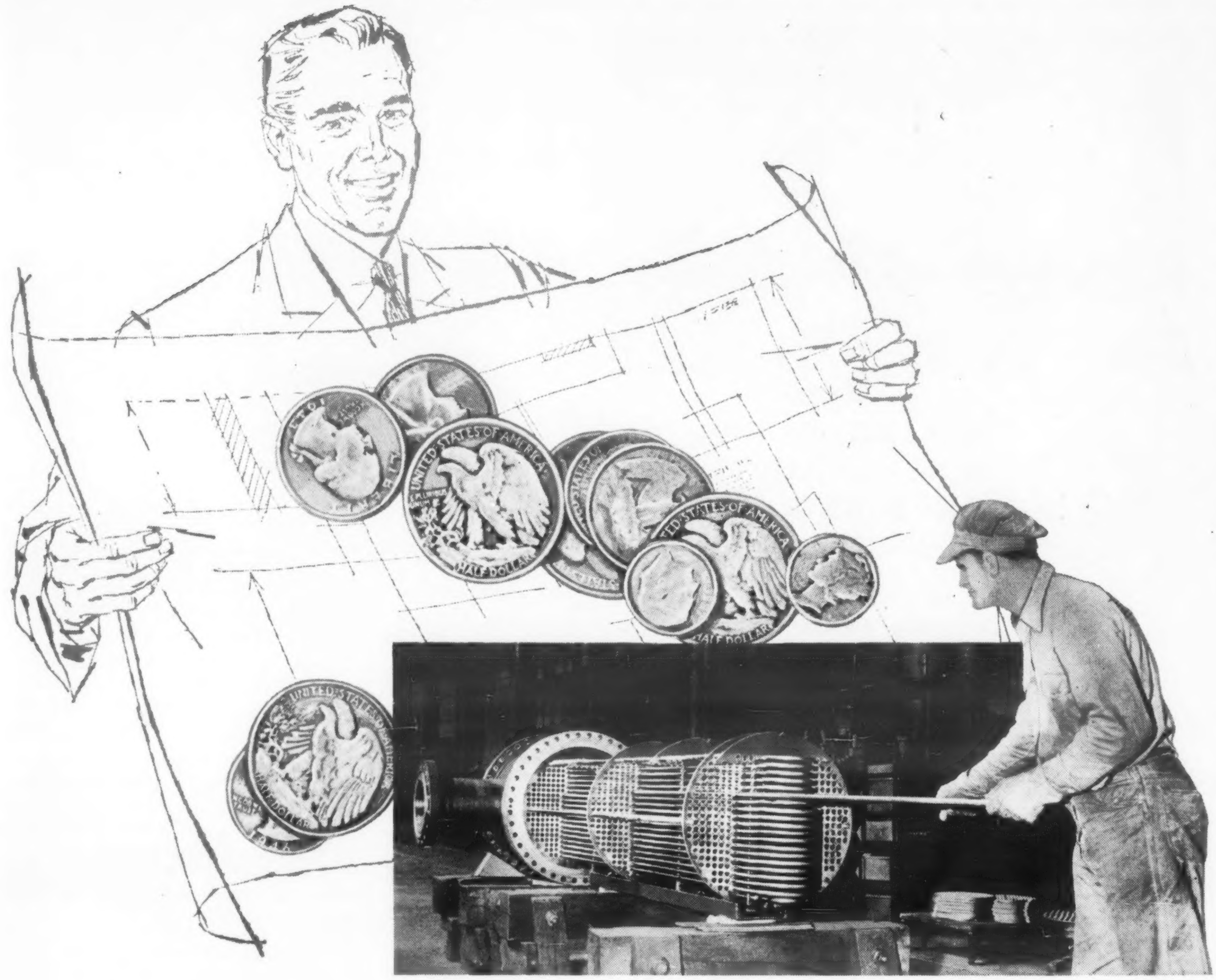
At the meeting of the Engineering & Research Committee of this association last week, the article "Thermal Insulation Materials" in your March issue was reviewed. The Committee was very pleased with this thorough review of the vital insulation field. However, Table 4 gives incorrect thermal conductivity values for 85% Magnesia, although those given in the text are correct. The correct figures for all four mean temperatures are: 0.35 (100 F), 0.38 (200 F), 0.42 (300 F), and 0.46 (400 F).

J. O. RONCEVIC
Administrative Secretary
Magnesia-Silica Insulation Mfrs. Assn.
Washington 4, D. C.

Flammable and noninflammable

To the Editor:

While scanning the May '58 issue I noted that in the box on p 101 the word "noninflammable" is used. I believe that safety engineers frown on the use of this apparent double negative in "noninflam-



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mable" which might make it appear to mean flammable. A substance that burns easily is flammable, but one that doesn't is nonflammable. I should think that the uniform use of these terms in your publication would help to avoid confusion.

WALTER H. KOHL
Research Associate
Stanford University
Stanford, Calif.

The Petroleum Institute and dictionaries state that "flammable" and "inflammable" are synonymous, though underwriters have found that many people incorrectly believe that inflammable means not flammable. The word which does *mean not flammable is "noninflammable" according to the dictionaries. "Nonflammable" is not listed. We therefore prefer "flammable" and "noninflammable."*

Metal refiners and producers

To the Editor:

We are looking for a directory listing refiners and producers of all metals, including selenium, lithium, tungsten, tantalum, etc.

B. L. FENTON
Intrametall A. G.
Zurich, Switzerland

We suggest the "List of Mineral Industries" published by the Bureau of Mines, Washington 25, D. C.

Asphalt for thermal insulation

To the Editor:

The interesting article, "Thermal Insulation Materials," in the Mar '58 issue discusses asphalt coatings on p 138. We manufacture such outdoor electrical substations as type "X SA-H". To prevent condensation, and also to insulate against winter temperature, the panels are lined with 1/8-in. thick cork.

It might be that we could obtain the same insulation with an asphalt coating. Can you give us the name of a few firms who supply asphalt coating for such use?

CLAUDE ROUSSEAU
President
Electrical Mfg. Co., Ltd.
Montmagny, Quebec, C.

Two suppliers are: Johns-Mansville Corp., 22 E. 40th St., New York, N. Y., and Lion Oil Co., El Dorado, Ark.

ONE POINT OF VIEW

Materials specialists must be trained to meet industry's needs

Because of the great number of engineering materials now available and the growing complexity of the materials selection function, there is an increasing demand for engineers with sound and detailed knowledge of the service properties and uses of all engineering materials. For this reason, we advocated on this page last month better education on materials for all engineers. In addition to this, however, there is a need for more comprehensive and intensive materials curricula in our engineering colleges to train materials specialists for industry.

Materials selection is vital

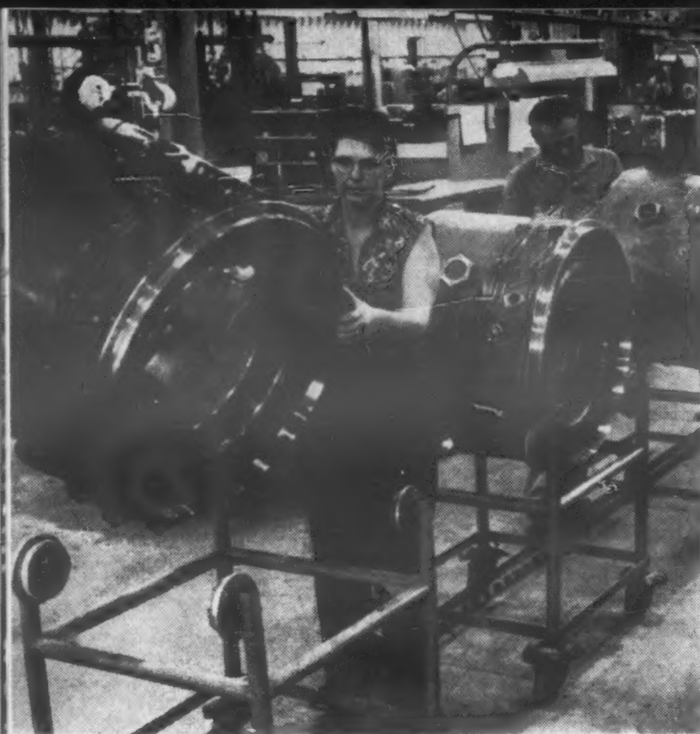
Most large manufacturing companies now have materials departments, and many medium size and small organizations have one or several technical men who serve as materials specialists. These departments and individuals play a vital role in the planning and production of industrial and consumer products. They often have the full responsibility of choosing materials for new or redesigned products. In other plants they serve as consultants to designers or review all materials choices before the product goes into production. In still other organizations they evaluate materials and prepare the specifications that materials must meet, and they work out materials problems encountered in production.

Staffing these departments is often difficult. Very few engineering graduates have had the benefit of courses designed for the user of materials. Because so few qualified men are available, it is usually necessary to spend valuable time training new men on the job.

More courses needed

As far as we know, only one college, the University of Michigan, now has a four-year curriculum in materials engineering. It has been in successful operation for six years, and about a year ago a graduate extension was established. The curriculum is designed to provide the student with a thorough knowledge of the engineering properties and processing characteristics of materials and the application of materials in parts and products. All metals, ceramics, polymers, and finishes are covered. Students completing such a course of study are certainly well equipped to meet the growing needs of industry for materials specialists.

To prepare more young men for jobs as materials specialists, we believe more engineering schools should offer a four-year course leading to a degree in engineering materials. Therefore, we hope other colleges will follow the University of Michigan's example and establish soon a materials engineering course.



Ryan Aeronautical Co.

Intermediate casings *for jet engines contain 17-22-AS and 410 stainless steel.*

Solar Aircraft Co.

Nacelle section *uses a 17-7PH structure and a AM-350 skin—said to be the first production use of AM-350.*

Which High Strength Steel?

Five new classes of steel—ranging in tensile strength from 150,000 to 310,000 psi—have shown promise for aircraft and missiles. Here are the advantages and disadvantages of each type . . . also new developments now underway.

by Robert J. Nekervis, C. H. Lund and A. M. Hall,
Titanium Metallurgical Laboratory, Battelle Memorial Institute

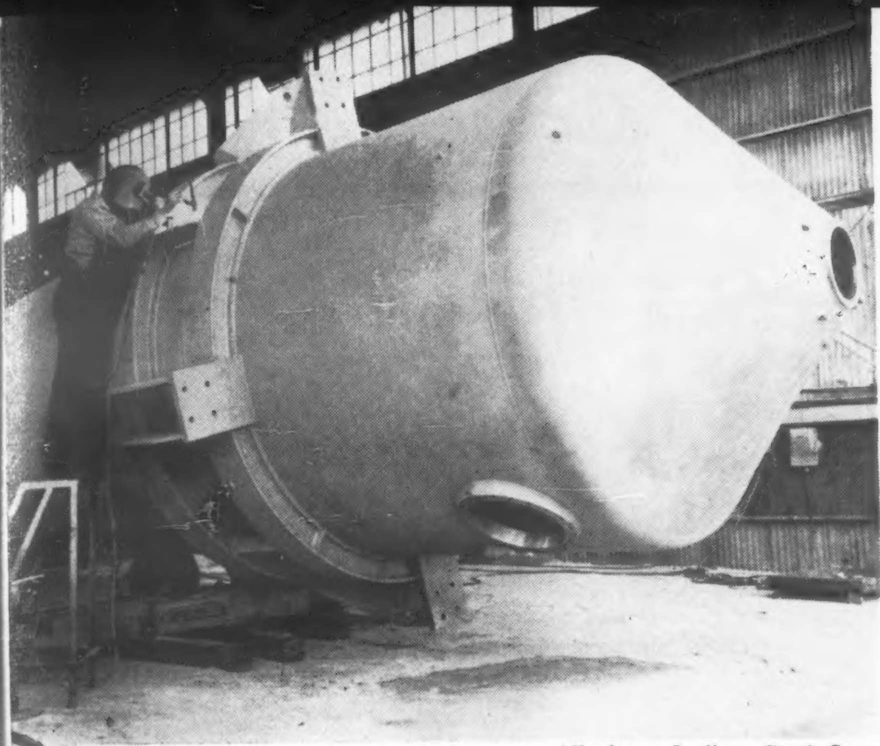
■ In order of decreasing tensile strength in the room temperature to 800 F range, the new high strength steels are: 1) the hot work tool steels, 2) the martensitic stainless steels, 3) the martensitic, low alloy hardenable steels, 4) the precipitation hardenable, semi-austenitic stainless steels, and 5) the precipitation hardenable, austenitic stainless steels. The advantages and disadvantages of a sixth type, cold rolled austenitic stainless steel, are well established in industry and are covered briefly at the end of the article.

1. Hot work tool steels

Advantages—The most important advantage of hot work tool steels over the more conventional high strength steels is that they offer greater resistance to softening at high temperatures. The reason is that they can be tempered at much higher temperatures than conventional steels for the same level of strength. In addition, hot work tool steels: 1) have the highest strength-weight ratio between 400-1000 F of any commercial structural metal; 2) have excellent ductility from —100 F to 1000 F; 3) are not notch sensitive (tensile strengths of notched specimens are higher than those of unnotched specimens); 4) are air hardened and therefore undergo less distortion during heat treatment than do low alloy steels such as AISI 4340; and 5) can be stretch formed in the softened condition.

Disadvantages—The most crucial disadvantage of hot work tool steels is that they do not contain enough chromium to make them stainless. As a result, they have not as yet been found too useful for exterior applications. One attempt to overcome this problem—cladding with austenitic stainless —has not worked out too well. As indicated in Fig 1 and 2, although the strength of the clad material is still impressive, the reduction is quite appreciable—40,000-50,000 psi from room temperature to 800 F. Another approach to the corrosion and oxidation resistance problem—hot dip aluminizing—has been more successful. It has recently been reported that the hot work tool steels can be aluminized in a bath of molten aluminum at 1350 F, the part being heat treated and the coating diffused at the same time. Other coatings, particularly diffused cadmium-nickel, also show promise.

As pointed out earlier, hot work tool steels are not, in general,



Allegheny Ludlum Steel Corp.

Fuel reservoir *for rocket engine system is made of types 321 and 347 stainless steel. Tank is 45 ft long and almost 8 ft in dia; it holds 9300 gal.*

Solar Aircraft Co.

JATO bottle *fabricated from Potomac M hot work tool steel has a tensile strength of 290,000 psi, a yield strength of 240,000 psi, and a burst pressure hoop stress of 253,000 psi.*

notch sensitive. However, some aircraft manufacturers point out that these materials (particularly the 5 chromium-1% molybdenum types) may be subject to brittle fracture under biaxial stresses below the tensile yield strength. Furthermore, bend ductility appears to be below requirements for pressure vessel applications.

Production problems associated with hot work tool steels include: 1) a tendency toward weld cracking, 2) poor oxidation and corrosion resistance (a protective coating is necessary even for storage), 3) difficulties in machining in the hardened condition, 4) liability to hydrogen embrittlement and decarburization, and 5) dimensional changes during martensitic transformation in heat treatment.

New developments—Higher strength, higher alloyed hot work tool steels are currently being researched by several companies. One high vanadium, high tungsten experimental sheet alloy is said to have a yield strength of 188,000 psi and a tensile strength of 210,000 psi at 1100 F. Going still higher in alloy content—toward the molybdenum-type high speed steels—yield strengths of 250,000 psi with tensile strengths of 309,000 psi at 1000 F have been achieved. Thus far, however, the room temperature ductility of these experimental steels is low, and modifications in composition are being tested in order to improve ductility.

2. Martensitic stainless steels

Advantages—Three main advantages are offered by martensitic stainless steels: 1) in general, their strengths are quite high, second only to those of the hot work tool steels, 2) their rates of cooling are slow enough to make them compatible with brazing, and 3) some of them have suitable resistance to crack propagation.

Disadvantages — The disadvantages inherent in the martensitic stainless steels are so severe that they are completely unusable in many cases. In fact, of all the major new steels for aircraft, less interest is being shown in these than in any of the others.

What is probably the most critical deterrent to the use of martensitic stainless steels for aircraft is their inadequate corrosion resistance. Because they must be coated in any case, most manufacturers feel that there is nothing to be gained by their use in preference to the stronger hot work tool steels. Moreover, in addition to sharing the disadvantages in welding, machining, hydrogen embrittlement, decarburization and warpage mentioned in connection with the hot work tool steels, they possess two additional negative factors: 1) tempering temperature levels necessary to achieve an optimum combination of tensile and impact strength fall into such a narrow range that they are extremely difficult to control in production; and 2) their composition sensitiveness makes reproducibility of strength levels very difficult.

New developments—Martensitic stainless steels are relatively new to the aircraft industry and a considerable amount of developmental work is now in progress. One experimental alloy, tempered at 900 F, shows typically a yield strength of 164,000 psi and a tensile strength of 210,000 psi at 900 F. The alloy is said to be quite stable, retaining 97% of its 800 F tensile strength after a 500-hr exposure at 800 F under a stress equivalent to 40% of the yield strength.

Experiments conducted on a sheet alloy show a 15% increase in tensile strength with the addition of copper to the analysis.

3. Martensitic low alloy hardenable steels

Advantages — The low alloy hardenable steels are character-

Properties of high strength steels

Crosshatched areas represent airframe and missile requirements.

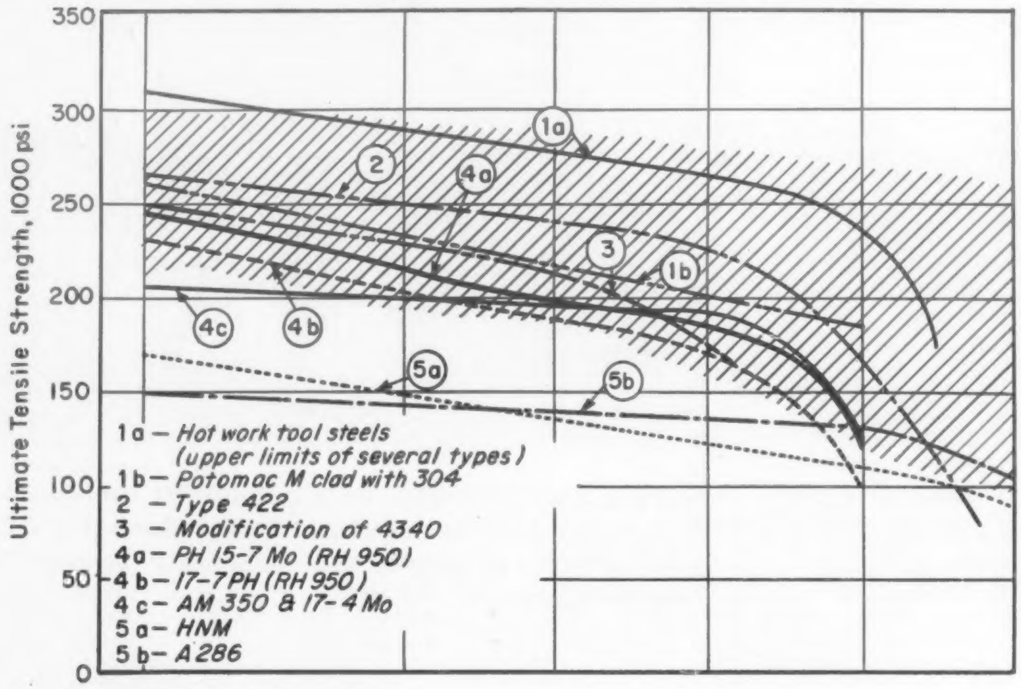


Fig 1—Tensile strength.

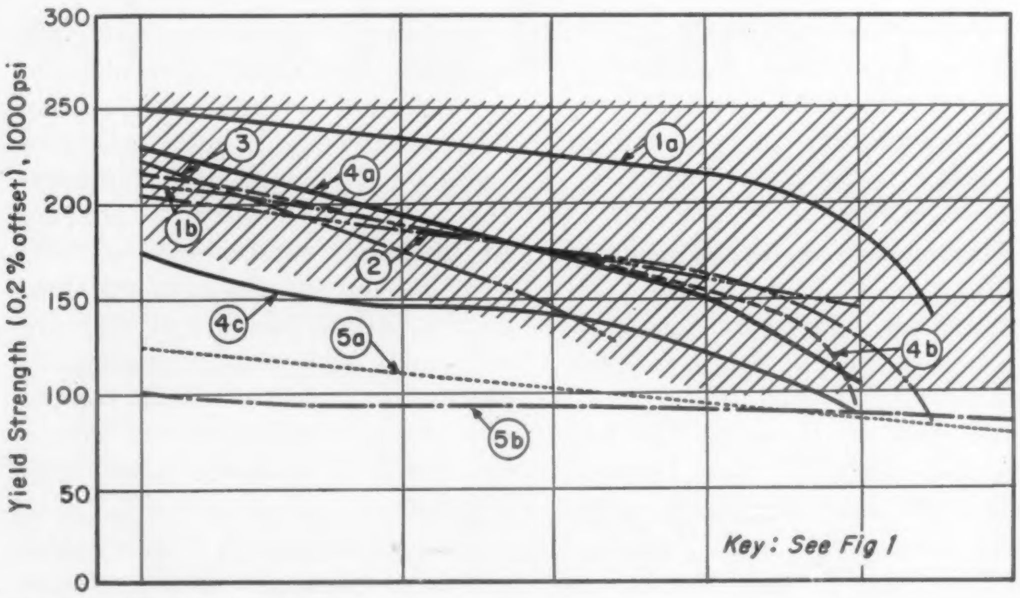


Fig 2—Yield strength.

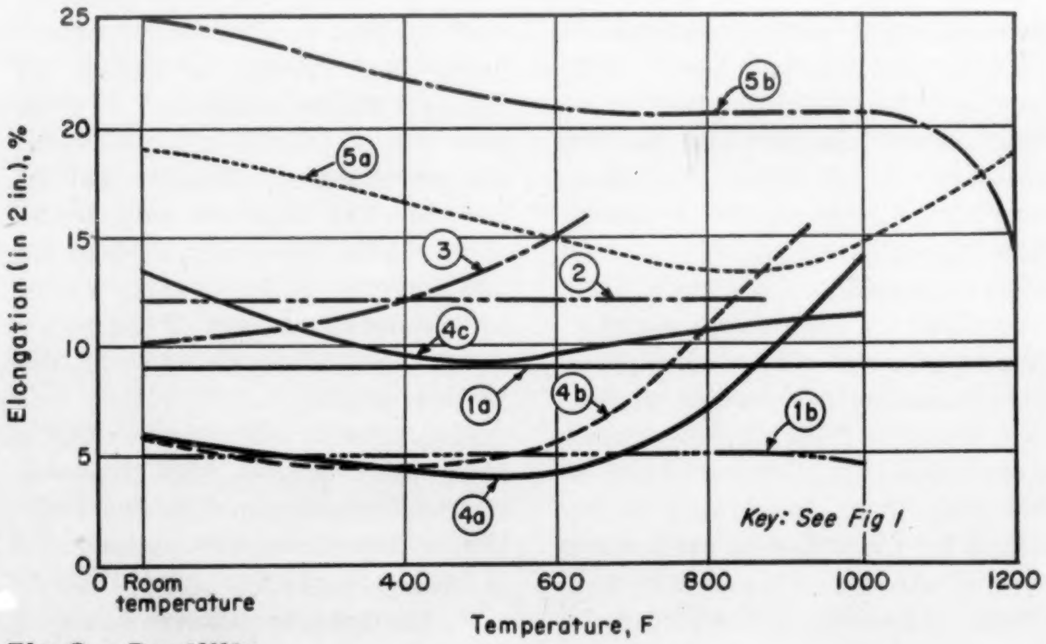


Fig 3—Ductility.

Some General Comparisons of the High Strength Steels

There are, of course, other factors besides tensile strength by which to judge the adequacy of a steel for aircraft applications. For example, whereas at room temperature the major design consideration would be tensile and yield strength, at elevated temperatures total creep or stress-rupture strength is the design limit. The reason for this is shown in Table 1 which compares the creep-deformation and stress-rupture characteristics of representative high strength steels with the short-time yield strengths at temperatures above 800 F.

Creep and rupture

As shown in the table, some steels exhibit creep and sometimes even rupture at stress levels considerably below the yield strength. The precipitation hardenable, semi-austenitic steels, on the other hand, have excellent stress-rupture strength—often higher than the yield strength—at 800 F. It is also evident from Table 1 that the relative standing of the steels in the range 800-1200 F is considerably different if the high temperature, long-time properties are taken as criteria.

Unfortunately, there is a dearth of information on creep strength on all of these steels, and only a very qualitative comparison is warranted. Isochronous creep curves (stress-strain curves at constant time and temperature) give more complete information and appear to be better design criteria. Thus far, however, such curves have been obtainable only for the precipitation hardenable, semi-austenitic steels and the precipitation hardenable, austenitic steels.

Yield strength ratio

Yield strength is a more important design criterion in aircraft than is the ultimate tensile strength and specifications often call for a minimum relationship between the two. In Air Force and commercial aircraft, for example, the yield strength is at least 67% of the ultimate; in Navy planes it is at least 74%. Accordingly, a general statement on the relationship between yield strength and ultimate tensile strength for the various grades of steels covered in this report may be useful.

For all the martensitic grades, the hot work tool steels, the 400 series stainless steels and the low alloy

TABLE 1—HIGH TEMPERATURE PROPERTIES

Steel	Condition	Time, hr	Temp, F	Load (1000 psi) to Produce Indicated Strain, %					Short-Time Yld Str (0.2% offset), 1000 psi
				0.1	0.2	0.5	1.0	Rupture	
1. Hot Work Tool Steels									
Halmo	Tempered at 1200 F	1000	1000	25	44	72	86	—	165
		100	1000	27	48	92	110	126	165
		0.5	1000	29	50	120	167	—	165
2. Martensitic Stainless Steels									
Type 422M	Tempered at 1200 F	1000	1100	—	—	—	—	38	87
		1000	1000	—	—	—	—	48	104
		1000	900	—	—	—	—	89	117
Type 422	Tempered at 1200 F	1000	1100	—	—	—	—	33	71
		1000	1000	—	—	—	—	60	87
		1000	900	—	—	—	—	68	98
3. Low Alloy Steels									
17-22-AV	Normalized at 1800 F, tempered at 1200 F (331-341 Bhn)	1000	1100	13	17	—	—	25	73
		1000	1000	35	—	—	—	49	92
17-22-AS	Normalized, tempered to 315 Bhn	1000	1000	17	23	—	—	60	92
4. Precipitation Hardening, Semi-Austenitic Stainless Steels									
17-7PH	TH 1050[a]	1000	900	15	18	25	—	52	90
17-7PH	RH 950[b]	1000	900	12.5	14	19	—	44	114
17-7PH	RH 950[b]	1000	800	31	36	50	—	92	138
PH 15-7 Mo	RH 950[b]	1000	800	95	109	—	—	170	152
PH 15-7 Mo	RH 950[b]	1000	900	40	44	58	—	108	132
AM-350	SCT[c]	1000	800	70	106	—	—	183	127
		100	800	—	—	—	—	189	127
5. Precipitation Hardening, Austenitic Stainless Steels									
A-286		1000	1200	28	32	40[d]	46	48	88
		1000	1100	63	67	72[d]	76	71	90
		1000	1000	76	83	87	89	87	88
		1000	1200	—	—	—	—	37[e]	80
		1000	1100	—	—	—	—	55[e]	83
		1000	1000	—	—	—	—	75[e]	86
		100	1200	—	—	—	—	50	80

[a]TH 1050: 90 min at 1400 F; air and water cooled to 60 F within 1 hr; 90 min at 1050 F; air cooled.
[b]RH 950: 10 min at 1750 F; air cooled, then refrigerated 8 hr at —100 F; 60 min at 950 F; air cooled.
[c]SCT (subzero cooling treatment): 3 hr min at —100 F; 3 hr min at 850 F; air cooled. Room temperature ultimate tensile strength: 198,000 psi.
[d]Creep strength in plastic strain. Relation to total strain is as follows:

	1100 F	1200 F
0.5% plastic strain, psi	72,000	40,000
0.5% total strain, psi	69,000	38,000

[e]Estimated from Crucible Steel Co.'s master rupture curve.

constructional steels, the yields fall within the general range of 75 to 80%. For precipitation hardenable, semi-austenitic stainless, the yield is in the order of 90% of the ultimate at room temperature, but falls to 80% at 1000 F. The yield strengths of precipitation hardenable, austenitic steels have a poorer ratio—65-75% of the ultimate—which is relatively constant with increasing temperature.

The ratio of yield strength to ultimate tensile strength can be improved by cold working. For semi-austenitic, precipitation hardenable stainless steels, cold work increases the ratio from 90% to as much as 97%. Research on the effect of cold work on precipitation hardenable, austenitic stainless steels shows that considerable improvement in the ratio is possible. Cold worked straight austenitic steels have yield

continued

ized by high strength at high temperature and are presently used for aircraft bolts. Their most salient advantage, however, is high strength at relatively low cost.

Most of the steels in this category rely on a normalizing treatment rather than on quenching treatments to obtain high strength at temperatures up to 1200 F, and they have higher creep and rupture strengths than any other low alloy steel—nearly equal to those of hot work tool steels. In addition, many of the alloys are not notch sensitive in stress-rupture tests below 900 F.

Disadvantages—In general, low

TABLE 2—COMPOSITION AND FORMS[a]

Steel ↓	Nominal Composition, %								Available Forms
	C	Mn	Si	Ni	Cr	Mo	V	Other	
1. Hot Work Tool Steels									
Peerless 56 (Crucible)	0.40	0.55	1.00	—	3.25	2.80	0.35	—	Bar, billets, sheet, strip, wire
Potomac M (Allegheny Ludlum)	0.40	0.35	1.00	—	5.25	1.25	1.00	—	Bar, billets, forgings, plate, sheet, strip, wire
Halmo (Crucible)	0.35	0.28	0.72	—	5.16	5.14	0.66	—	Bar, billets, sheet, strip, wire
Vasco Jet 1000 (Vanadium-Alloys)	0.40	0.30	0.90	—	5.00	1.30	0.45	—	Bar, billets, rod, plate, sheet, wire
Thermold J (Universal Cyclops)	0.50	0.35	1.10	1.40	5.00	1.30	1.00	—	Bar, billets, forgings, sheet, wire rounds
Potomac A (Allegheny Ludlum)	0.40	0.30	0.90	—	5.00	1.30	0.50	—	Bar, billets, forgings, plate, sheet strip, wire
Dynaflex (Latrobe)	0.40	0.30	0.90	—	5.00	1.30	0.45	—	Bar
2. Martensitic Stainless Steels									
Type 418 Special (Allegheny Ludlum)	0.17	0.50 max	0.50 max	2.00	13.0	0.50 max	—	3.00 W	Bar, billets, forgings, wire
Type 422 (Crucible)	0.22	0.65	0.35	0.70	12.0	1.00	0.25	1.00 W	Bar, billets, sheet, strip, wire
Type 422M (Crucible)	0.28	0.85	0.25	0.20	12.0	2.25	0.50	1.70 W	Same as above
12MoV (U.S. Steel)	0.25	0.50	0.50	0.70	12.0	1.0	0.30	—	Bar, billets, plate, sheet, strip, wire
3. Martensitic Low Alloy Steels									
17-22-A (Timken)	0.45	0.50	0.65	—	1.25	0.50	0.25	—	Bar, billets, sheet, strip, tubing, wire
17-22-AS (Timken)	0.30	0.50	0.65	—	1.25	0.50	0.25	—	Same as above
17-22-AV (Timken)	0.28	0.75	0.65	—	1.25	0.50	0.85	—	Same as above
4. Precipitation Hardening, Semi-Austenitic Stainless Steels									
PH 15-7 Mo (Armco)	0.07	0.60	0.40	7.00	15.00	2.25	—	1.15 Al	Bar, billets, plate, sheet, strip, foil
17-7PH (Armco)	0.07	0.60	0.40	7.20	17.10	—	—	1.15 Al	Same as above
AM-350 (Allegheny Ludlum)	0.10	0.90	0.40	4.20	17.0	2.75	—	0.10 N	Bar, billets, forgings, plate, wire
17-4 Mo (Universal Cyclops)	0.10	0.90	0.40	4.20	17.0	2.75	—	0.10 N	Bars, billets, forgings, sheet, strip, wire
AM-355 (Allegheny Ludlum)	0.13	0.95	0.50 max	4.35	15.50	2.75	—	0.10 N	Bar, billets, forgings, plate, wire
5. Precipitation Hardening, Austenitic Stainless Steels									
HNM (Crucible)	0.30	3.50	0.50	9.50	18.50	—	—	0.25 P	Bar, billets, sheet, strip, wire
A-286 (Allegheny Ludlum, Firth Sterling and Universal Cyclops)	0.50	1.35	0.95	26.0	15.5	1.25	0.30	0.20 Al, 2.00 Ti	Bar, billets, forgings, plate, sheet, strip, tubing, wire
COLD ROLLED AUSTENITIC STAINLESS STEELS									
301	0.10	0.80	0.50	7.00	17.00	—	—	0.15 N	Bar, billets, forgings, sheet, strip, foil, wire
201	0.10	7.00	0.75	4.00	17.00	—	—	0.10 N	Same as above
Tenelon (U.S. Steel)	0.10	14.50	0.50	—	17.00	—	—	0.40 N	Sheet, strip

[a]Based on manufacturers' releases.

continued

strengths that approach the ultimate, depending on the degree of cold working.

Graphical comparisons

Typical tensile and yield strengths of representative steels of the various types now in use or being considered are shown in Fig 1 and 2 against a background (cross-hatched area) of airframe and missile manufacturers' requirements. Ductility values of these steels are compared in Fig 3. Composition, sources and availability of these and some other steels are given in Table 2.

alloy hardenable steels have the same disadvantages already mentioned in connection with martensitic stainless steels and hot work tool steels, namely, 1) they are difficult to weld, 2) they are prone to hydrogen embrittlement, 3) they must be jigged during heat treatment to avoid distortion, and 4) they are difficult to machine in the hardened condition.

New developments—In order to overcome the problem of hydrogen embrittlement, several manufacturers have been trying to develop

new electroplating methods. However, discovering a combination of electroplating and subsequent baking treatments which gives consistent freedom from embrittlement has proved to be a very difficult task. Sonic agitation of the plating bath and shot peening of the steel before electroplating are two techniques that seem promising. Vacuum depositing of cadmium and electroless nickel plating appear to be promising methods by which to avoid the entire problem of hydrogen embrittlement.

Several ceramic coatings, some of which contain aluminum, have been found to successfully withstand a 500-hr, 1000 F life test.

4. Precipitation hardenable, semi-austenitic stainless

Advantages—Of the newer aircraft steels, the precipitation hardenable, semi-austenitic stainless type is rapidly becoming the workhorse. The reason for this is that this type of steel combines the higher strength obtainable by martensitic transformation with "stainlessness" and ease of fabrication. These steels can be formed and then hardened with a minimum of scaling, and the expansion that occurs in the martensitic transformation frequently can be taken up in the forming operation.

These steels can also be satisfactorily brazed, and welding is possible by either fusion or resistance techniques.

Disadvantages—The most serious disadvantage exhibited by the precipitation hardenable, semi-austenitic stainless steels is their tendency to embrittle with time at temperatures above the 600-800 F range. Other disadvantages: 1) low ductility; 2) composition limits too wide to permit uniform response to heat treatment; and in some of these steels, 3) poor resistance to crack propagation.

New developments—In addition to several relatively new higher strength modifications (such as PH 15-7 Mo and AM-355), a major advance in this class of steels is a new method of hardening. The new technique, which involves cold rolling between the annealing and aging steps, is said to improve strength (minimum room temperature tensile strength is 240,000 psi), reduce intergranular corrosion, take up martensitic dimensional change, and reduce the amount of undesirable retained austenite.

5. Precipitation hardenable, austenitic stainless

Advantages—At temperatures above 1000 F the precipitation hardenable, austenitic stainless steels are, in general, superior to all others. These alloys have better ductility and resistance to creep in the 1000-1200 F range than does any other high strength steel. Corrosion resistance of these steels is generally equivalent to that of type 304, and oxidation resistance is equivalent to that of type 310.

Forming qualities of these steels are excellent, and they can be welded either by shielded arc or inert-gas shielded arc methods.

Disadvantages—The chief disadvantage of these steels is low strength at intermediate and room temperatures. Cold working between the solution and aging treatments greatly increases the degree of aging and provides a phenomenal increase in strength. But, when processed in this manner, the steels have the obvious disadvantage of all cold worked steels; namely, directionality of properties and reduced ductility.

New developments—Even higher strength steels of this type are presently being investigated by several companies. One of these, a cold rolled nickel-free alloy, has a room temperature tensile strength of 230,000 psi and a yield strength of 193,000 psi. However, the ductility of this particular steel is quite low—about 2%. Another possibility is a 16 chromium-6% nickel, vanadium-modified steel which is expected to be able to meet a minimum 1200 F tensile specification of approximately 120,00 psi.

Extensive experimental work is also being done on nickel and/or cobalt-base superalloys.

Other High Strength Alloys

Cold rolled austenitic stainless steel

When attention is focused on the newer types of high strength steel which are now available or becoming available to the aircraft industry, it is easy to overlook the fact that the bulk of the high strength steel used by the industry today consists of the ordinary stainless grades. These steels, AISI 301, 302, 304 and 347, and the low nickel varieties such as 201 and 202, possess a combination of desirable properties: 1) they are readily welded, 2) they have fairly good (and, in several conditions, extremely high) strength, and 3) they have good corrosion resistance. Primary disadvantages are low ductility and directionality of properties.

A new development in cold rolled stainless is U.S. Steel's Tenelon, a 0.10 carbon-14.5 manganese-17 chromium-0.40% nitrogen, nickel-free alloy which has a room temperature tensile strength of 210,000 psi, a yield strength of 190,000 and an elongation of 7%. Composition and available forms of representative cold rolled austenitic stainless steels are listed in Table 2.

Iron-aluminum alloys

The Thermenols are an altogether different series of iron-base alloys which contain from 10 to 18% aluminum and from 2 to 4% molybdenum. The low density of these alloys (0.24 lb per cu in.), combined with their excellent resistance to corrosion and high temperature oxidation, and their retention of room temperature strength up to 1000 F, make them appear promising for aircraft applications.

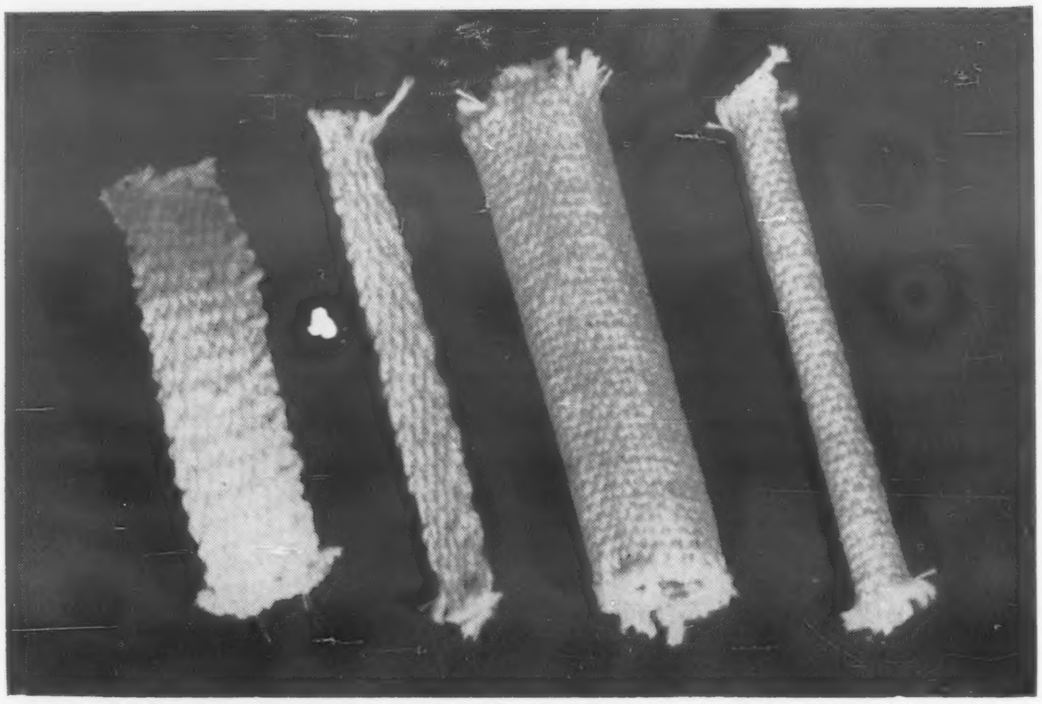
However, the Thermenols exhibit two distinct disadvantages: 1) in spite of their low density, they do not measure up to the semi-austenitic stainless steels when strength-weight ratios as a function of temperature are compared; and 2) they are extremely difficult to form, grind or machine because they have low ductility below 900 F, are poor heat conductors and work harden quite rapidly.

'Engineered' Fabrics

Here's What They Can Do

You can get a wide range of properties in specially constructed fabrics using various combinations of fibers and impregnants. These photos and accompanying captions tell how custom-made fabrics are used in nine product designs to meet a variety of service conditions

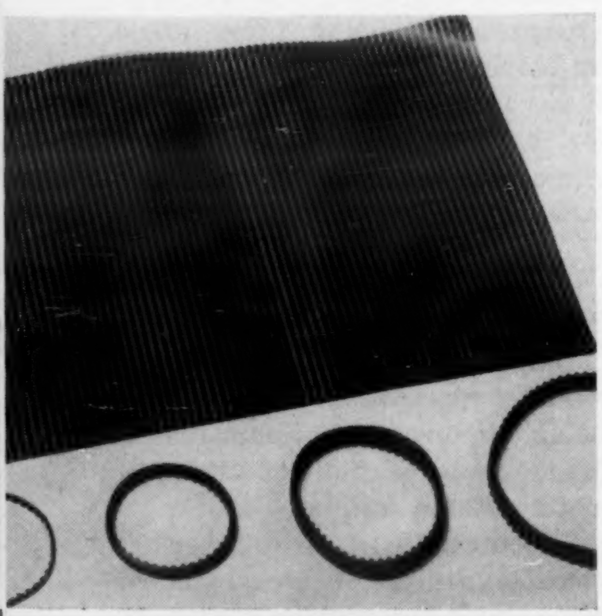
by L. A. Runton,
President, Russell Mfg. Co.



High temperature insulation. These fabrics are woven of aluminum silicate fibers which retain their properties up to 2000 F and will not melt below 3000 F. In addition to heat resistance, the fabrics provide high strength, low thermal conductivity (about the same as glass and rock wool), and high resistance to common acids.

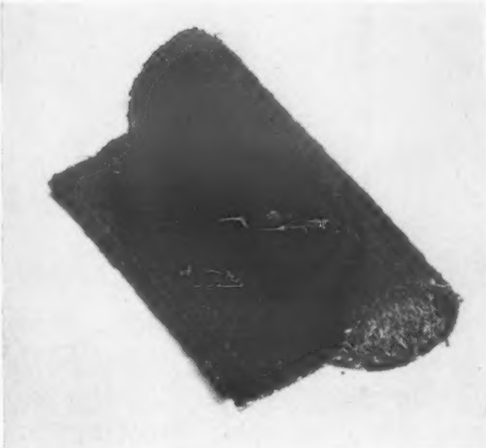
The fabrics are available in flat and tubular forms, and are used to insulate pipes and electrical cables in applications such as atomic reactors and missiles. The flat tapes can be woven in a wide variety of sizes for heat (as well as electrical) insulations, and are commonly fastened with a high temperature, zirconium oxide cement.

Of particular interest is the tape at the left which is a high temperature instrumentation tape used in atomic submarines to detect leaks. The current-carrying wires are made from a nickel-chromium alloy and are arranged so that a short circuit results if they are bridged by sodium or similar metals. The short circuit activates a low voltage relay to produce a warning signal. Life of the tape is 1500 hr at 1500 F.

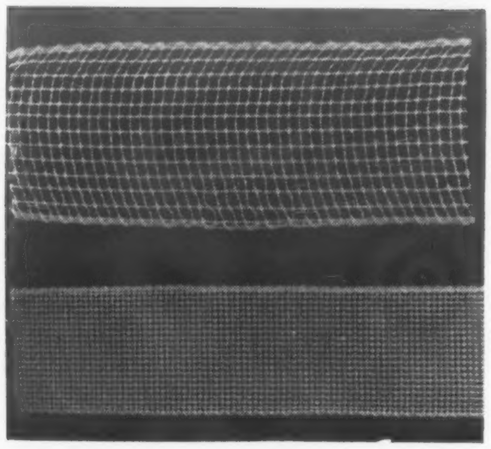


Precision geared belts. These geared belts are made from polyvinyl chloride reinforced with cotton and are cut from cylindrical sleeves (a typical sleeve which has been cut open to show the teeth is shown at the top). Principal advantage of the geared belt is that it combines the simplicity of a flat belt drive with the slip-proof feature of chain and gear drives. The belts can be used in conjunction with epoxy plastic or metal powder gears, or in some cases with just a knurled shaft. Miniature and subminiature belts of this type are used in instrumentation devices, business machines, and tape recorder drives where accurate timing is required.

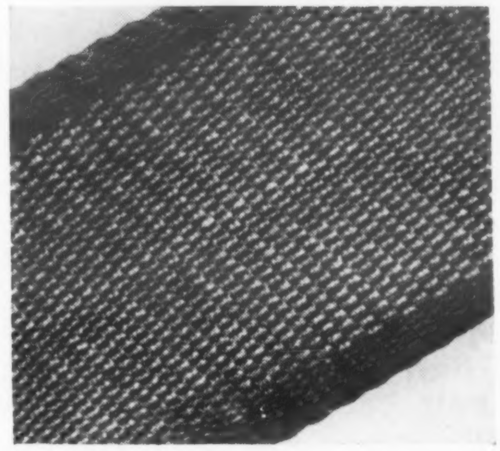
In general, the cotton-reinforced polyvinyl chloride belts are satisfactory for most uses below 150 F. Special belt materials are available where extra resistance to heat, oil, water or solvents is required. Depending on the application, belts can be made from Dacron, glass fibers, silicone rubber and neoprene.



Compressible fire resistant seal. This compressible seal consists of a loop-shaped glass, asbestos, or aluminum-silicate fabric jacket which has been treated with a fire resistant adhesive. It is is filled with stainless steel wool around which is wrapped a coil spring. The seal has excellent high temperature properties and, because of its porous construction, will not wick oils or gasoline. It is also very light in weight and returns to its original shape after compression. Principal uses of the seal are in engine hatches, aircraft bulkheads and industrial oven doors.



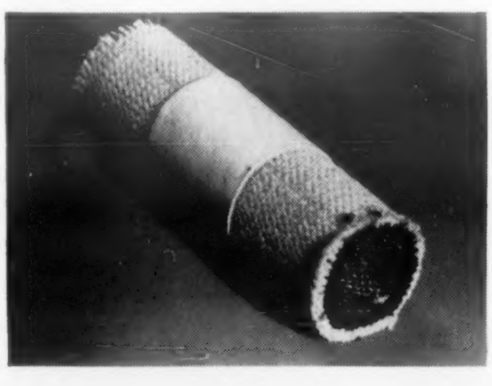
Formable reinforcing fabrics. These two glass fabrics are woven (somewhat like mosquito netting) in such a way as to leave large squares in the fabric. They are frequently formed around electrical cables, where they serve as a reinforcing layer for rubber, polyvinyl chloride or other resin impregnants. Such fabrics are also used in the production of molded fiberglass products such as boats, and for reinforcing the edges and seams of miscellaneous fabrics.

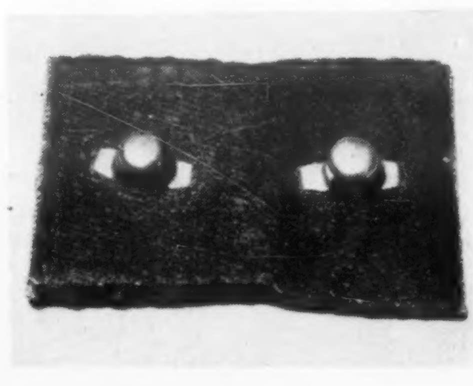


Flexible conveyor belt. This composite fabric is woven with bronze and stainless steel wires in the warp and TFE (polytetrafluoroethylene) multifilament yarn in the fill. The fabric is used principally as a flexible apron in a conveyor for the high temperature curing of plastics. The flexible stainless steel-TFE apron has long life and can be used at temperatures up to 400 F.

Lightweight flexible bearings. Shown at the *left* is a lightweight, flexible bearing having a very low coefficient of friction because of the TFE filaments used in its construction. The longer tube is made from a two-ply weave consisting of an inner layer of multifilament TFE and an outer layer of high strength, spun Dacron yarn impregnated with a high temperature silicone rubber. The two-ply tube is encased in a short, shock resistant rubber tube.

In use, a rotating metal shaft is inserted inside the long tube and a clamp is fastened over the short outside tube to pre-stress the bearing and take up any play. The bearing can be used in high temperature aircraft applications and other uses where a lightweight, high strength bearing with resistance to vibration is required. It does not require any lubrication and is well suited as a bearing for aircraft trim tabs and auxiliary equipment.

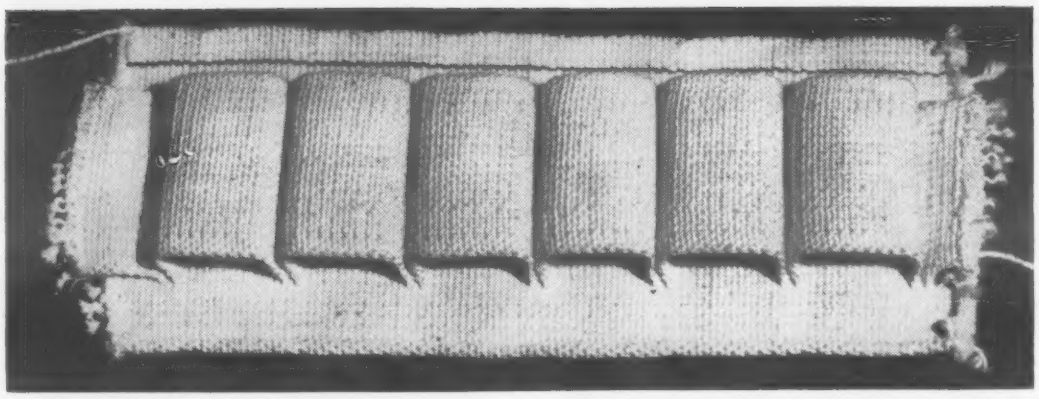




Shown at the *right* is a cotton textile which can be impregnated with such low friction materials as carbon black, graphite or wax. When fitted with two studs, the webbing is used as a low friction insert between the leaves of automobile springs. The material withstands considerable shock, requires no lubrication, and is relatively inexpensive.

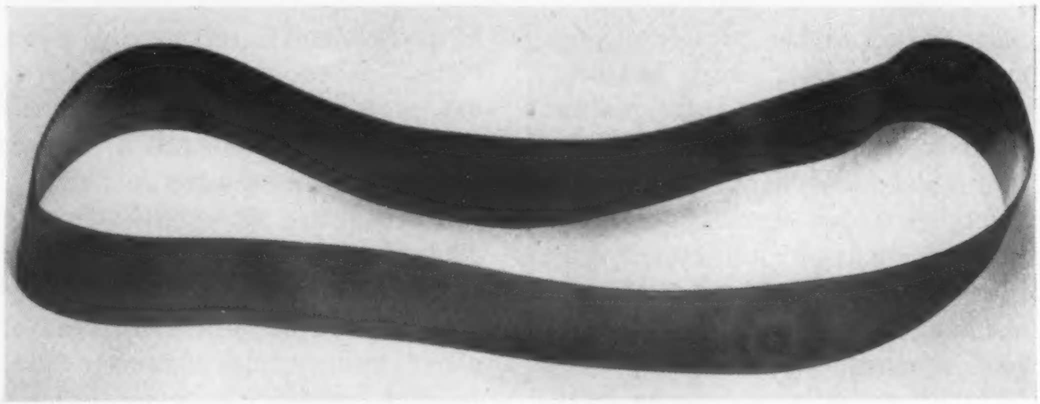
Shock resistant belt. A unique feature of this belt is its shock resistant, duplex fabric construction consisting of a series of loops integrally woven into a flat backing. When made of such high strength yarns as Dacron, nylon, Fortisan, etc., these belts can be used for stowing parachute cords. During launching the cords are released evenly; the shock of release does not tear the loops because of their integral construction.

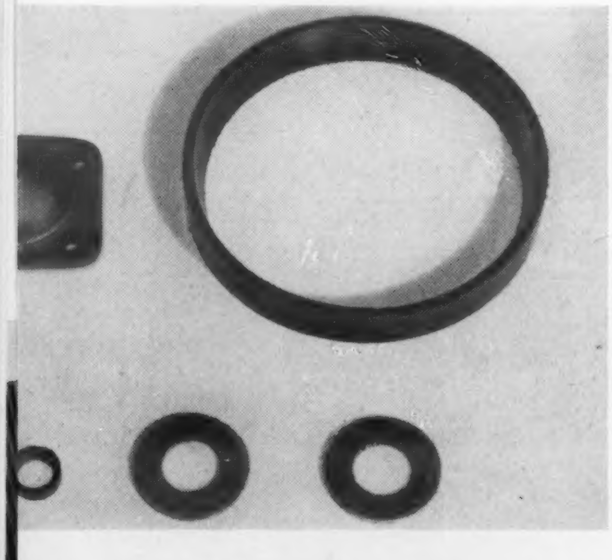
This same type of belt can be used as a bearing lubricator in heavy-duty applications. The belt is woven from a spun Dacron or Orlon yarn, and the loops are filled with an oil-absorbing vinyl or polyurethane sponge. When used in freight car journals, the fabric is laid into the journal box and the loops are pressed upward against the rotating axle shaft.



High speed, lightweight belt. This very lightweight, high strength belt can be run at speeds up to 100,000 rpm. The endless belt is made from a special Dacron cord yarn sleeve that is impregnated as many as 16 times in a polyurethane rubber impregnant, then vulcanized. The sleeves are formed such that the belts cut from it contain cords that pass endlessly around each belt.

The belts are made in two thicknesses, both suitable for high speed operation. Miniature belts from 17 to 20 mils thick are used in such applications as dentists' drills and can be operated up to 100,000 rpm. Thicker belts—from 35 to 40 mils thick—are used in heavier-duty applications, such as grinder spindles operating at 80,000 rpm which are used in the manufacture of ball bearings.





Self-lubricating bearings. Here are five different types of phenolic-impregnated fabrics that are used in applications requiring no lubrication, a low coefficient of friction and high strength.

The steel stamping at *upper left* is an experimental unit used in front wheel automobile bearings. The inner surface (not visible) of the cup is lined with a fabric containing TFE multifilament yarns which are impregnated with a phenolic resin and molded in place. The impregnated fabric has very good adhesion to the stamping, excellent strength, and a low coefficient of friction; it does not need to be lubricated. The same type of bearing can also be used in such heavy-duty applications as hydroelectric, earthmoving and marine equipment, and for applications requiring a low break-away torque over a wide temperature range.

Construction of the bearing shown at the *upper right* is similar to that of the automobile bearing described above. This large part is used as a hemispherical bearing support in a helicopter and must operate under extremely rigorous conditions.

The impregnated TFE fabric molding shown at the *lower left* is used as a bearing support in an aircraft application. It replaces a brass bushing, providing a much lower coefficient of friction at low temperatures and requiring no lubrication.

Both of the bearings shown at the *lower right* are also made from impregnated TFE multifilament yarns. The part in the center is a low friction thrust washer used in automobile front-end ball joints. The part at the right consists of a three-ply fabric in which the TFE yarn is so thoroughly interspersed that no matter where it is cut there is enough yarn to form a bearing surface. Five or six of these disks can be slipped over the end of a journal to act as a composite bearing surface which does not require any lubrication.

Guide to Materials Standards and Specifications

Part 5—Nonmetallics (*except Plastics and Rubber*)

by S. P. Kaidanovsky,
Consulting Engineer

■ Standards and specifications on nonmetallics (other than plastics and rubber) are prepared or issued by most of the Governmental agencies and national organizations, such as the Federal Supply Service, Dept. of Defense, Commodity Standards Div. of the U. S. Dept. of Commerce, American Society for Testing Materials, Society of Automotive Engineers and American Standards Assn. Their standardization activities were covered in Part 1 of this series.

In addition, a number of trade and technical societies concerned with nonmetallics prepare standards or assist standards agencies: the Industrial Mineral Insulation Manufacturers Institute, Inc., the Felt Assn., the American Ceramic Society, and the National Electrical Manufacturers Assn. The activities of the last organization were covered in Part 4 of this series.

The standards and specifications on nonmetallics issued by the various organizations are summarized in the accompanying table.

Where to Obtain Standards for Nonmetallics

American Society for Testing Materials
1916 Race St., Philadelphia 3.
ASTM Standards, Part 3—Refractories, Glass, Ceramics, Thermal Insulation; Part 4—Wood; Part 6—Electrical Insulation; Part 7—Textiles, Paper.
Each standard available separately.[a]

Society of Automotive Engineers
485 Lexington Ave., New York 17.
SAE Handbook. Each AMS available separately.[a]

Federal and Military
Supt. of Documents, U. S. Government Printing Office, Washington 25, D. C.
Each specification available separately.

Commercial
Commodity Standards Div., Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.
Each standard available separately.[a]

American Standards Assn.
70 E. 45th St., New York 17.
Each standard available separately.[a]

National Electrical Manufacturers Assn.
155 E. 44th St., New York 17.
NEMA Standards Publications, List and Order Blank. Varnished Fabric and Paper. Mica.
Each standard available separately.

[a] See first article (Mar '58) for information on index.
Use of standards issued by trade associations should not be considered mandatory.

Industrial Mineral Insulation Manufacturers Institute

The Industrial Mineral Insulation Manufacturers Institute (IMIMI) is a trade association concerned with the use of mineral wool insulation for industrial purposes. The institute's member-

This is the fifth in a series of six articles. The last article will deal with organizations and standards on finishes and coatings. All articles in this series will later be made available as a reprint (75¢).

ship is composed of producers of rock, slag and glass fibers. To encourage the manufacture of quality products, the institute has fostered the development of voluntary industry standards, known as Commercial Standards (see Part 1, Mar '58). These standards have been developed and adopted according to the standards procedure of the Commodity Standards Div., U. S. Dept. of Commerce.

The institute's technical committee assists in the preparation of Federal Specifications, and also works closely with the American Society for Testing Materials by participating in ASTM Committee C-16 on Insulation. The institute also cooperates with the American Society of Heating and Ventilating Engineers.

American Ceramic Society

The purpose of the American Ceramic Society is to promote the art, science and technology of ceramics. The society consists of the following divisions: Enamel, Glass, Materials and Equipment, Refractories, Structural Clay Products, and White Wares. Each of these divisions has a standards committee.

The ACS does not issue its own standards, but carries on a considerable amount of work in the development of standards and specifications through representation on committees of the American Society of Testing Materials. The chairman of the standards committee of the ACS White Wares Div. is also the chairman of ASTM Committee C-21 on Ceramic Whitewares.

Felt Assn.

The Felt Assn. (FA) is composed of manufacturers, distributors and cutters of felt. The association does not issue its own standards, but cooperates with several standardization agencies. It has developed a standard for wool felt, which has been adopted as a Commercial Standard and issued by the Commodity Standards Div. of the U. S. Dept. of Commerce. The standards committee of the association cooperated with the Society of Automo-

SUMMARY LIST OF STANDARDS AND SPECIFICATIONS

Organization	Type of Document	Document Identification[a]	Materials, Forms Uses
ASBESTOS			
ASTM	Spec	CXXX	Cement, laminated asbestos, cellular asbestos. Thermal insulation
ASTM	Spec	D299[b]	Yarn. Electrical uses
ASTM	Spec	DXXX	Cloth, tape, roving. Electrical uses
ASTM	Spec	DXXX	Lap. Thermal insulation
Federal	Spec	HH-I-561	Thermal insulation
Federal	Spec	SS-C-466	Cloth, thread, tape. Electrical uses
Military	Spec	MIL-A-7021	Sheet. Gaskets
Military	Spec	MIL-C-4117	Cloth, tape. Electrical uses
Military	Spec	MIL-I-XXX	Fiber, board. Electrical uses
SAE	Mtl Spec	AMS 3840	Polytetrafluoroethylene-impregnated. Aeronautical uses
FELT			
ASTM	Spec	DXXX	Mechanical sheet and roll felts. General uses
Comm. Dept.+FA	Comm. Std.	CS185	Wool felt. General uses
Federal	Spec	C-F-XXX	Pressed wool felt, hair felt. General uses
Federal	Spec	HH-I-XXX	Laminated felt, asbestos felt. Thermal insulation
Military	Spec	MIL-I-XXX	Asbestos felt, glass fiber felt. Thermal insulation
Military	Spec	MIL-F-XXX	Hair felt, wood fiber. Aeronautical and general uses
SAE	Std	—	Mechanical roll felt. Automotive and general uses
GLASS			
ASTM	Spec	CXXX	Cellular glass. Thermal insulation
ASTM	Spec	D1459	Silicon-varnished glass fiber cloth. Electrical uses
Federal	Spec	DD-G-451	Flat and corrugated glass. General uses
Federal	Spec	HH-I-551	Cellular glass. Thermal insulation
NEMA	Std	GFX	Yarn, staple, filament. Electrical uses
NEMA	Std	VFX	Glass fiber cloth. Electrical uses
Military	Spec	MIL-G-XXX	Glass fiber cloth (coated and uncoated)
Military	Spec	MIL-G-XXX	Laminated glass, plate glass, bullet resistant glass
Military	Spec	MIL-I-XXX	Fibrous glass. Thermal insulation
Military	Spec	MIL-I-XXX	Glass fiber cloth, tape. Electrical uses
Military	Spec	MIL-S-3787	Flat laminated safety glass
Military	Spec	MIL-T-XXX	Glass fiber tape
SAE	Mtl Spec	AMS 3676	Resin-bonded glass fiber filament. Sound and thermal insulation. Aeronautical uses
SAE	Mtl Spec	AMS 36XX	Glass fiber cloth. Aeronautical uses
INDUSTRIAL TEXTILES			
ASTM	Spec	DXXX	Cotton. Cloth, tape. Electrical uses
ASTM	Spec	DXXX	Cotton. Cloth, sheeting, tape. General and electrical uses
ASTM	Spec	DXXX	Cotton, rayon, nylon, fibrous glass. Flexible treated sleeving. Electrical uses
Federal	Spec	DDD-T-86	Cotton. Tape. General uses
Federal	Spec	HH-C-471	Varnished cotton. Cloth, tape. Electrical uses
Federal	Spec	HH-I-528	Cotton. Batt. Thermal insulation
Military	Spec	JAN-T-414	Cotton. Tape
Military	Spec	MIL-C-5646	Cotton. Cloth. Aeronautical uses
Military	Spec	MIL-I-XXX	Cotton, rayon, synthetic. Fiber, yarn, cloth, tape. Electrical uses
Military	Spec	MIL-T-XXX	Cotton, rayon-cotton. Tape
NEMA	Std	VFX	Cotton. Cloth, tape. Electrical uses
NEMA	Std	48-140	Varnished silk. Cloth. Electrical uses
SAE	Mtl Spec	AMS 38XX	Cotton. Cloth (mercerized). Aeronautical uses

[a]*XXX* in the document identification indicates that more than one standard has been developed on the material. Revisions, amendments and year are not indicated. When ordering, the latest issue is supplied.
[b]American Std. ASA L14.18.

FOR NONMETALLICS (Except Plastics and Rubber)

Organization	Type of Document	Document Identification[a]	Materials, Forms, Uses
MICA			
ASTM	Spec	DXXX[c]	Natural mica Block, film. Electrical uses
Federal	Spec	HH-I-XXX	Natural muscovite mica, pasted mica. Electrical uses
Military	Spec	MIL-I-XXX	Mica paper, pasted mica. Electrical uses
NEMA	Std	ME1	Electrical uses
MINERAL WOOL			
ASTM	Spec	CXXX	Felt, blanket, batt, molded, block, cement. Thermal insulation
Comm. Dept. +IMIMI	Comm. Std.	CSXXX	Thermal insulation
Federal	Spec	HH-C-168	Cement. Thermal insulation
Federal	Spec	HH-I-XXX	Felt, block, board, blanket, batt. Thermal insulation
Military	Spec	MIL-I-XXX	Blanket, fibrous sheet. Thermal insulation
WOOD AND PAPER			
ASTM	Spec	C352	Compressed cork. Thermal insulation
ASTM	Spec	DXXX	Sulfate paper. Electrical uses
Federal	Spec	HH-C-576	Compressed cork, granulated cork. Gasket, sheet. Thermal insulation
Federal	Spec	LLL-F-321	Fiberboard. Thermal insulation
Federal	Spec	LLL-I-533	Redwood bark. Thermal insulation
Federal	Spec	HH-I-515	Vegetable or wood fiber. Thermal insulation
Military	Spec	JAN-I-545	Pressboard. Electrical uses
Military	Spec	MIL-B-XXX	Paper. Barrier material, protective use
Military	Spec	MIL-I-695	Slot cell paper. Electrical uses
NEMA	Std	48-138	Condenser paper. Electrical uses
SAE	Mtl Spec	AMS 37XX	Paper honeycomb. Aeronautical uses
OTHER NONMETALLICS			
ASTM	Spec	CXXX	Calcium silicate. Thermal insulation
Federal	Spec	HH-I-523	Calcium silicate. Thermal insulation
Military	Spec	MIL-C-18482	Cemented carbides (titanium carbide, tungsten carbide). Naval radioactive system service
Military	Spec	JAN-I-10	Ceramics. Electrical uses
ASTM	Spec	CXXX	Diatomaceous earth. Thermal insulation
Federal	Spec	KK-L-XXX	Leather. Hydraulic packing
Military	Spec	MIL-L-17314	Leather. Hydraulic packing
ASTM	Spec	CXXX	85% magnesia. Thermal insulation
Federal	Spec	HH-I-554	85% magnesia. Thermal insulation
ASTM	Spec	CXXX	Refractories
ASTM	Spec	C196	Vermiculite (hydrous silicate). Cement. Thermal insulation
Federal	Spec	HH-I-578	Vermiculite (hydrous silicate). Thermal insulation

[c]American Std. ASA C59.26 and ASA C59.27.

tive Engineers in developing the SAE Standards on felt, and assists in the preparation and revision of Federal and Military felt specifications. The association works closely with the American Society for Testing Materials and is represented on the ASTM committees of concern to the felt industry.

Felt Designations

SAE Grades — The commonly used grades of automotive felts are designated by a letter *F*, followed by a number *1, 2, 3*, etc., such as *F1, F2, F3*, etc. The number indicates the grade, based on thickness, weight, wool content, chemical and physical requirements, color and width of felt.

Felt Assn., ASTM, Federal and Commercial Standards—The designations in these standards consist of three parts: a number, a letter and a number. The first number indicates the "surface density" (unit weight in lb/sq yd/1-in. thickness). Letter *S* indicates felt fabricated in sheets, and letter *R* indicates felt fabricated in rolls. The second number indicates the type based on fiber composition and chemical and physical properties. Thus, a felt designated *26S1* is a type 1 sheet felt having a surface density (or unit weight) of 26 lb/sq yd/1-in. thickness. Since the density designation applies to all sheet felts of the same unit weight in all thicknesses, thickness must be specified separately following the density and type designation.

ASTM designations

Designations for flexible, treated sleeving (organic and inorganic) used for electrical insulation are given in ASTM D372-53T. The designation consists of two letters and a number. The first letter indicates the class of insulation from the standpoint of temperature limits:

	Temp Limit
Class A	220 F
Organic base (cotton, rayon, nylon or other organic fibers) impregnated or coated with organic substance.	
Class B	266 F
Inorganic base (fibrous glass or other inorganic fibers) impregnated or coated with organic substance.	
Class H	392 F
Inorganic base (fibrous glass or other inorganic fibers) impregnated or coated with silicone compounds.	

The second letter and number following the class letter indicate the electrical grades of the material according to their performance characteristics, such as dielectric breakdown, heat aging, disintegration or swelling in transformer oil, resistance to potting temperature, and burning rate.

Highlights of Process

Investment castings so small that 125 can be placed in a 10¢ aspirin box are now in commercial production. These castings are the smallest of the miniature investment cast parts now competing successfully with parts made by other high production metalworking operations such as screw machining, cold heading and stamping.

Defined as parts having a volume of less than 1 cu in., miniature investment castings can be produced at a rate of 25,000 to 50,000 parts per day, in contrast with the usual investment casting production rate of 500 to 1000 per day. The process, known as the Minicast Process, is particularly adapted to difficult-to-machine materials because the close tolerances obtained reduce or eliminate machining requirements.

Metals cast — Among suitable metals are the high alloy steels, tool steels, superalloys and stainless steels. Low alloy steels can also be cast if desired. Of the nonferrous metals, only magnesium alloys and the high-zinc copper alloys are not suitable among common alloys. The process has not been applied to such metals as titanium and zirconium.

Shapes cast — Shape limitations are less severe in miniature investment castings than in other high production methods. Complex parts can be produced readily. The smallest cross section produced in commercial operations to date is 0.032 in. thick, but parts as thin as 0.020 in. have been produced experimentally.

Tolerances held—As-cast tolerances on these miniature investment castings are normally held to ±0.005 in. per in. but some dimensions can be held to ±0.003 in. per. in. At least 75% of the castings now in production are produced as precision blanks and are subsequently coined or cold headed to improve dimensional accuracy. Tolerances on these parts are held to ±0.003 in. per in. and some dimensions can be held to ±0.001 in. per in.

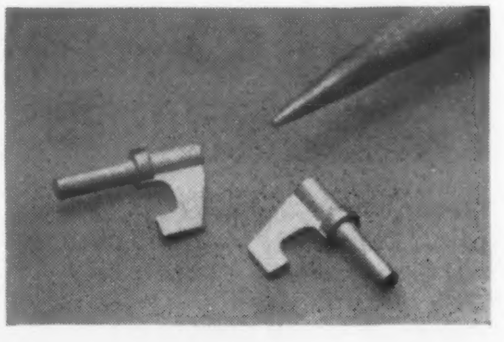
Comparative cost—Although miniature investment castings are made at high production rates, they cannot compete with simple screw machine parts. On the other hand, they are definitely competitive with screw machine parts that require secondary operations. They are also competitive in overall cost with stamped parts produced in multiple-slide or eyeletting machines, and with coined or forged parts requiring secondary operations.

Here are 7 typical cases where

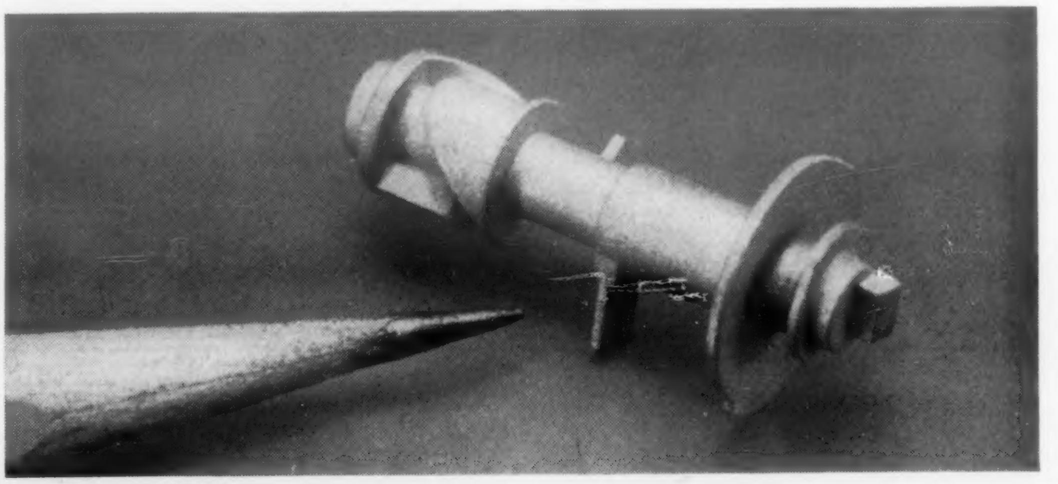
Miniature Investment Castings

proved less costly than stampings, forgings and screw machine parts.

by Vincent S. Lazzara, *President, Casting Engineers, Inc.*

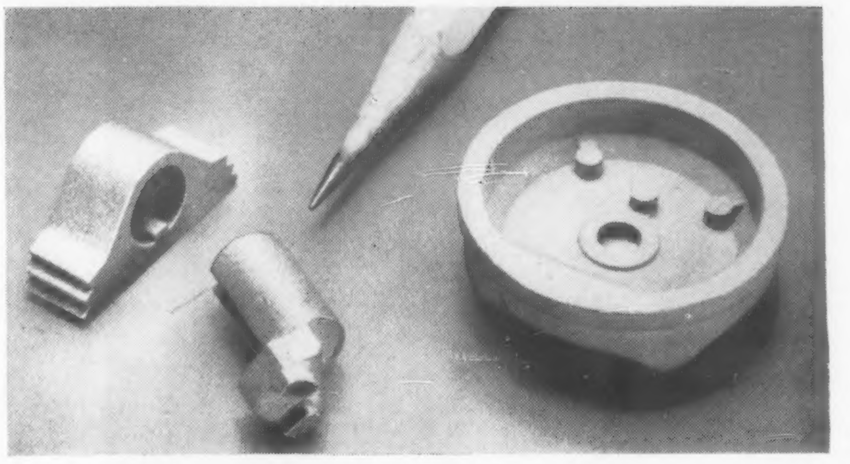


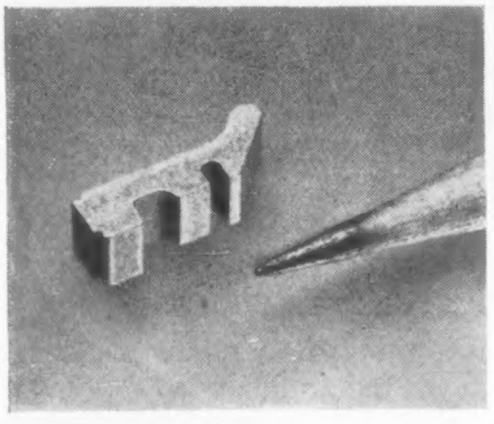
Deflector chad, part of a perforating accessory, is used on a teletype machine. Formerly produced from low carbon steel as a stamping that required subsequent machining and coining, it is now investment cast from silicon-manganese tool steel to improve toughness and abrasion resistance. This is probably the smallest part ever investment cast for commercial use. Overall length is less than 0.200 in.; the flag portion is only 0.045 in. thick. Critical dimension is held to ±0.001 in. per in. Converting from a stamping to an investment casting reduced the cost 62%.

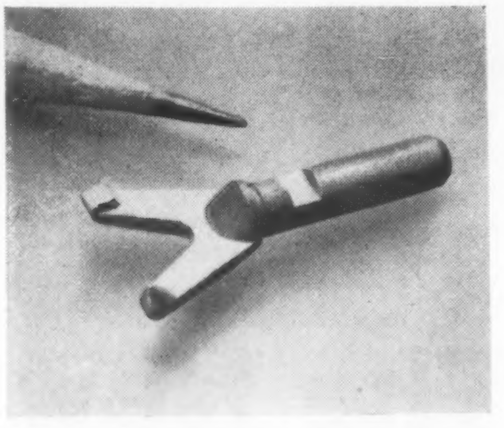


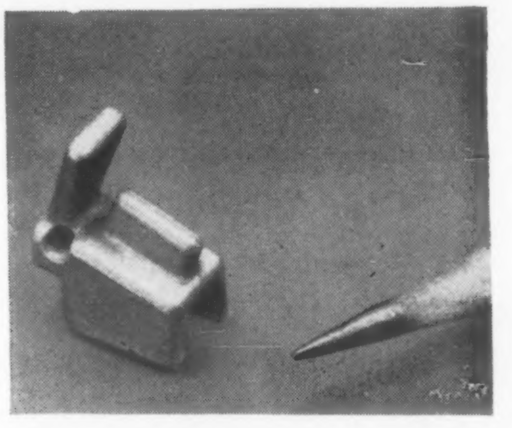
Power shaft to control shutter speed and timing mechanism on a 35-mm camera. The part was formerly made from 1020 steel on an automatic screw machine and required extensive milling as a secondary operation. Converted to an investment casting of AISI 8640 chromium - nickel - molybdenum steel, the part requires only drilling as a secondary operation. A cost reduction of 67% was realized partially because tolerances of ±0.002 to 0.005 in. per in. could be held on the casting in difficult-to-machine areas. More than 250,000 of these parts have been made by investment casting.

Reversal stud, pawl and plate used in an automatic ratchet wrench. These parts were formerly produced from 8660 steel by machining forgings. Conversion to investment casting permitted strict tolerances to be held so that teeth, key and keyway required no machining. The investment cast parts, subsequently hardened to Rockwell C50-55, are as strong as the forgings used previously. The investment cast parts have better surface finish than the forgings, an additional advantage on exposed surfaces. Cost saving is 40%.









Coupling—part of a quick disconnect coupling for hydraulic and air lines. The part was formerly machined from extruded 8620 steel bar stock and required subsequent carburizing, milling and sawing. The part is now investment cast from tool steel and is heat treated to 200,000 psi tensile strength. The change in material has extended service life; the change in production method has reduced cost by 25%.

Fork yoke that oscillates the cutting blade on sheep shearing equipment. The part was formerly forged from C1117 steel, and subsequent machining, milling and carburizing operations were required. Now it is investment cast from 8620 chromium-nickel-molybdenum steel. Several critical dimensions are held to ±0.0015-0.002 in. per in. The only secondary operation required is centerless grinding of the shaft. Overall cost saving is 20%.

Saliva ejector body, produced from type 302 stainless steel, is used in dental work as a clamping mechanism during the filling of cavities. Formerly machined, it is now investment cast. The as-cast surface can be polished to the required finish in far less time than the original machined surface, thus reducing the production cost (exact figures not available).

Knotter assembly parts used on a hay baler. Previously forged from 4615 steel and machined, these parts (*right*) required extensive hand filing to provide smooth contours. The parts are now investment cast from the same steel (and carburized to a depth of 0.020 in. for maximum wear resistance). The castings have uniform contours and surface finish is superior to that of the forgings. Cost has been reduced by 15%.

Phillips Chemical Co.

***Toughness**—combined with rigidity—is one of the important benefits gained in using polyethylenes of higher density.*

Koppers Co.

***Heat resistance** of Type III polyethylenes permits their successful use in defroster ducts and heater defroster outlets for cars.*

An up-to-date report on

The New Polyethylenes

Part 1

Commercial grades
Combinations of properties available
Latest creep, stress-rupture data
Resistance to stress cracking, sterilization

by Malcolm W. Riley, *Associate Editor, Materials in Design Engineering*

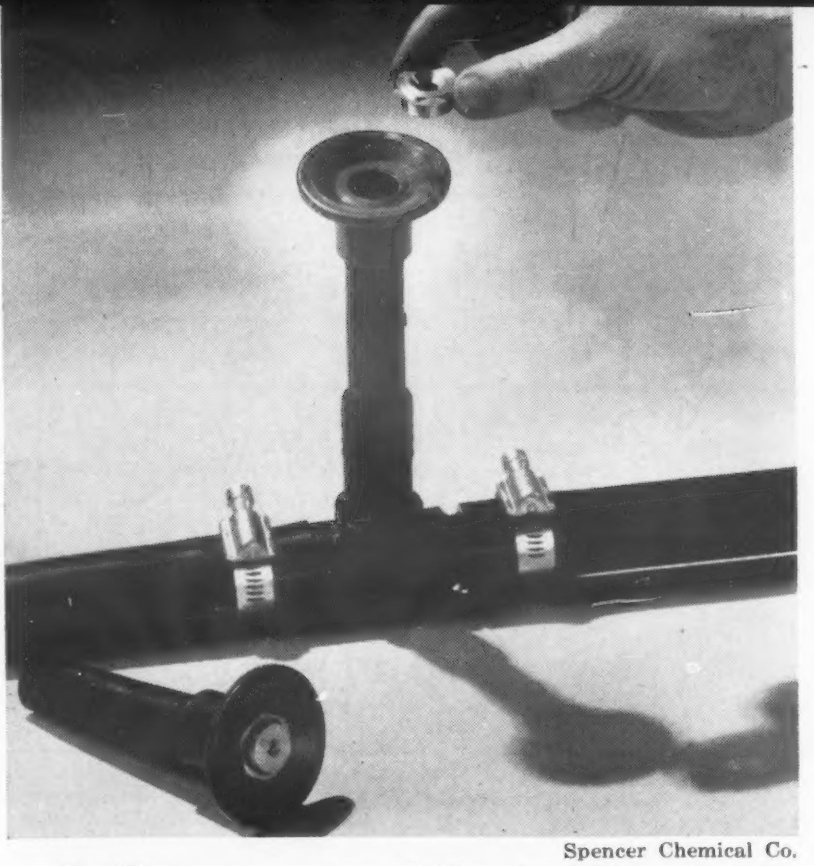
■ In the past few years a number of new polyethylene plastics have been developed to extend the range of engineering properties offered by conventional polyethylene. The importance of the new resins lies in the unique combination of properties provided by their relatively high densities: in general, high rigidity and strength, resistance to temperatures above the boiling point of water, and a hard glossy surface (see "Rigid, Heat Resistant Polyethylenes," MATERIALS & METHODS, July '55, p 88).

The new materials are conveniently divided (by a recently proposed American Society for Testing Materials classification) into two groups: *Type II* or "medium density" materials (0.926-0.940 gm per cu cm), produced by a modified high pressure process, and *Type III* or "higher density" materials (0.941-0.965 gm per cu cm), produced by either the Ziegler or the Phillips low pressure process. The conventional "lower density" materials (0.910-0.925 gm per cu cm), produced by the high pressure process, are known as *Type I*.

Each of these density ranges is quite broad in itself. However, density is not the only significant indicator of properties; at any given density, properties vary considerably with the melt index of the material. Thus, the many different combinations of density and melt index make available a still larger family of polyethylenes, each member of which has a unique combination of properties.

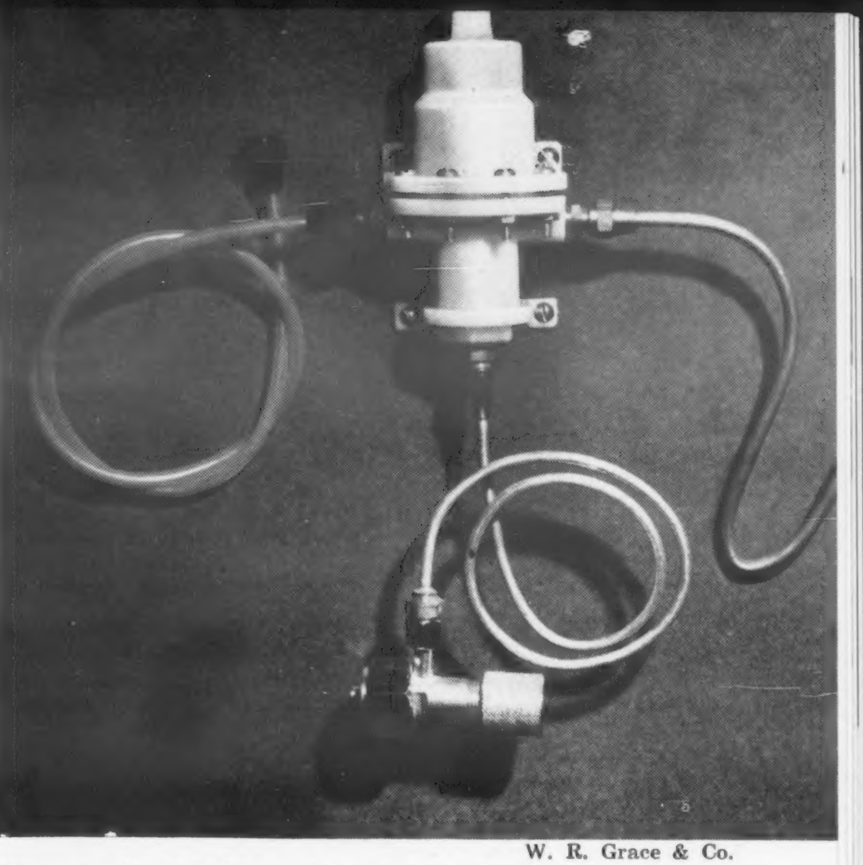
Commercial grades

Table 1 lists the density and melt index-dependent properties of commercial Type II and III polyethylenes. Where possible, the properties are organized by melt index at each density level. The table does not indicate breadth of molecular weight distribution, since the practical use of this parameter appears problematic (see box, p. 102). Also, since these data were developed in the laboratories of various companies, too precise a comparison may be mis-



Spencer Chemical Co.

***Resilience,** as well as rigidity, is obtained by using Type II polyethylene in this molded sprinkler head for lawn watering systems. Resilient head prevents lawn-mower breakage.*



W. R. Grace & Co.

***Chemical stability** inherent in polyethylenes, coupled with the rigidity and strength resulting from higher densities, make Type III polyethylenes suitable for such uses as this chlorine safety shut-off valve molded by Blackwell Plastic Molding Co.*

leading. Producers should be consulted to aid in the final selection of type and grade.

In general, an increase in density provides: 1) greater rigidity and strength, 2) higher temperature resistance, 3) a harder, glossier surface, 4) higher resistance to creep and stress-rupture, 5) lower permeability to fluids and gases, and 6) decreased film coefficient of friction. On the other hand, as density increases, impact strength and flex life decrease.

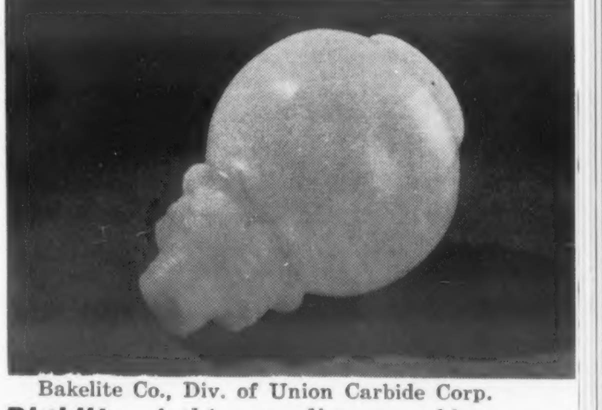
At any given density level, a decrease in melt index (indicating higher molecular weight) provides: 1) increased impact strength, 2) greater resistance to environmental stress cracking, 3) higher elongation, 4) lower brittleness temperature, and 5) improved creep and stress-rupture resistance. On the other hand, as melt index decreases, melt fluidity and "drawability" decrease, making the material more difficult to process. Although these effects of melt index generally hold true for any of the Type II or III polyethylenes, the magnitude of the effects on various properties differs with density.

Other properties, such as chemical stability, dielectric characteristics (see Table 2), flammability and resistance to weathering are largely unaffected by density or molecular characteristics of polyethylenes. The higher density materials have better resistance to certain chemicals than the lower density materials, thus where chemical stability is critical, tests under the specific service conditions should be made. Dielectric constant also increases very slightly with density — on the order of an 0.05 difference between 0.92 and 0.96 density.

Ultraviolet resistance of Type II and III materials is comparable to that of Type I material. Carbon black is used in both types to provide long-term resistance to ultraviolet degradation. Any additive (such as a pigment) that will absorb or screen out ultraviolet improves weathering characteristics of all polyethylenes.

Creep and stress-rupture

Development of data describing time-dependent characteristics of materials requires tests extending over a substantial period of time. Because of the newness of Type II and III polyethylenes, data of this type are quite limited and spotty. However, several indicative creep and stress-rupture curves have been developed for materials of various densities and melt indexes, giving an idea of the type of service that can be expected.



Bakelite Co., Div. of Union Carbide Corp.

***Rigidity** of this soap dispenser, blow molded of Type III polyethylene, prevents emptying by squeezing; toughness of the material prevents breakage in public toilets.*

Investigations to date indicate that though higher density materials provide lower creep deformations, density alone is not enough to describe their behavior; melt index has an important effect.

Fig 1 compares creep of two Type II resins of similar densities (0.930 and 0.931 gm per cu cm) but quite different melt indexes. The creep elongations are approx-

TABLE 1—TYPICAL PROPERTIES OF

		Type II				Type III		
Density, gm/cu cm ➔		0.930		0.934	0.935	0.945		0.947
Melt Index, gm/10 min ➔		12.0	1.9	3.5	1.0	0.2[c]	[d]	0.6[c]
	ASTM Method							
Izod Impact Str, ft-lb/in. notch	D256	—	—	No break	No break	3-6	8-12	1.5-4.0
Elongation (ultimate), %	D412	100	400	100[f]	400[fh]	—	—	—
	D638	—	—	—	—	100-700	100-700	100-700
Brittle Point (50% failure), F	D746	−158	−165	−100[f]	−100[f]	< −76	< −76	< −76
Stiffness Modulus, 1000 psi	D747	43	45	49[f]	50[f]	85-115	85-120	90-110
Tensile Strength, psi	D412	1500	1600	2100[f]	2200[fh]	—	—	—
Yield Strength, psi	D412	2100	2100	1900[f]	2100[fh]	—	—	—
	D676	—	—	—	—	4400	4500	3450
Hardness (Shore D)	D676	55	55	57[f]	58[f]	65	65	66
Softening Point, F		222[b]	224[b]	232[b]	237[b]	250[b]	250[b]	250[b]
Heat Distortion Point, F	D648	—	—	—	—	113[i]	113[i]	113[i]

[a]Classification of properties by specific melt indexes is not available.
[b]Vicat softening point.
[c]Nominal.
[d]No melt index given; value of 4.5-6.0 is given for reduced specific viscosity, indicating extremely high molecular weight.
[e]Properties are in direction of flow.
[f]Obtained on compression molded samples.

Note: These grades have been selected as representative and do not represent all grades of Type II and III materials available.

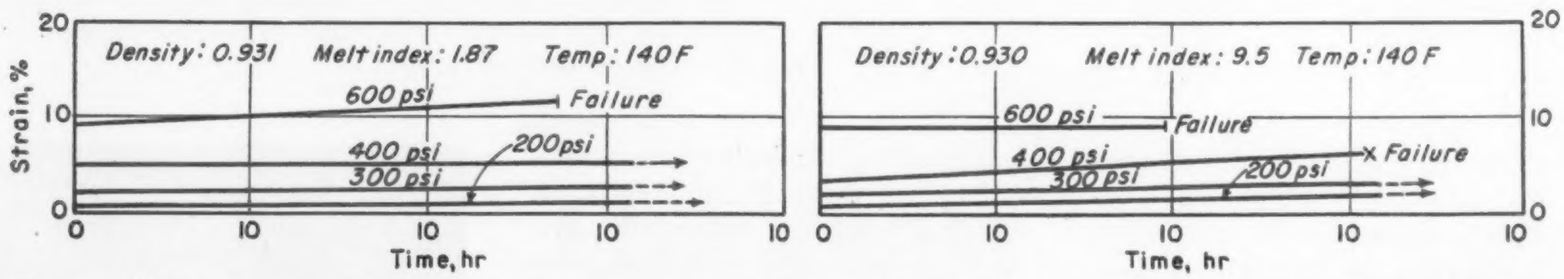


***Fig 1**—Creep characteristics of two Type II (medium density) polyethylene of similar densities but different melt index. Though creep elongations are similar, the higher melt index material ruptures in a shorter time.* (Carey)

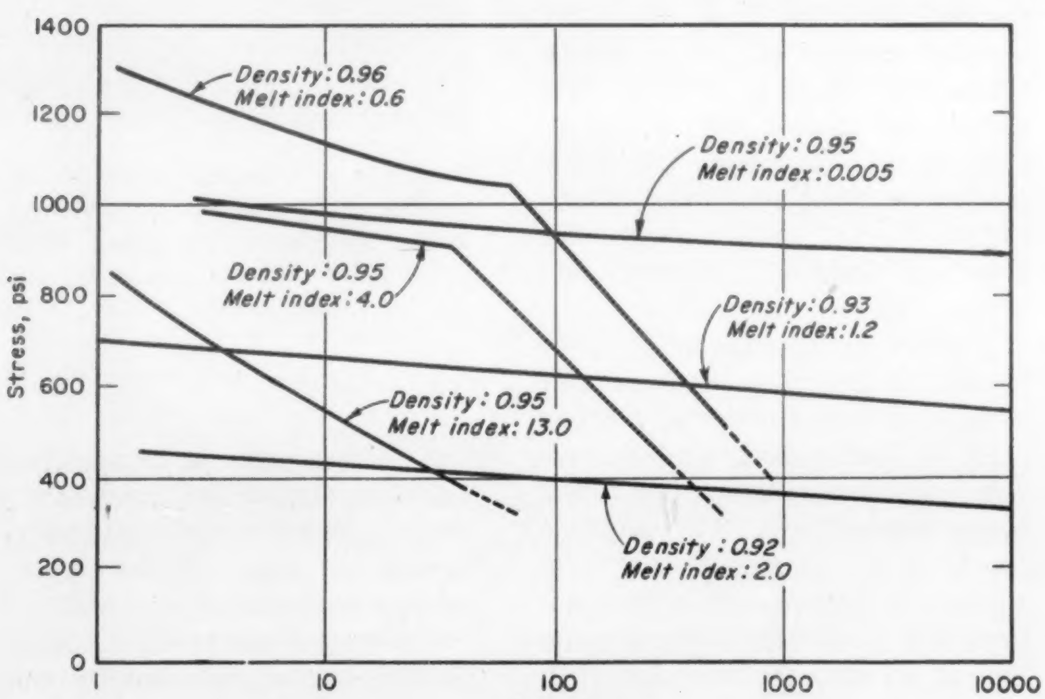


***Fig 2**—Stress-rupture curves show the effect of altering melt index at various densities.* (Carey)

imately equal, but rupture occurs sooner and at a lower stress for the resin with the higher melt index.

Fig 2 shows the differences in stress-rupture characteristics of several polyethylenes of different densities and different melt indexes. According to *Carey*, density governs the creep or elongation characteristics, but a low creep rate does not necessarily guarantee long life. Materials having a low melt index (high molecular weight) have a greater probability of survival.

Fig 3 shows creep rates for two Type III (0.947 and 0.96 gm per cu cm density) resins of low melt indexes at various stresses.

Data showing the effect of elevated temperatures on time-dependent characteristics are very limited. In general, as would be expected, an increase in temperature increases the creep rate for any given applied stress, and decreases the time to rupture.

Environmental failures

Failures due to *thermal embrittlement* (loss of mechanical properties after exposure to elevated temperatures below the crystalline melting point) have become more evident as higher density polyethylenes have been used more widely for heat resistant applications. Although this

Type III (Continued)									
0.950			0.955	0.96					
7.5-8.5	1.5-2.5	0.3-0.5	0.1->12.0[a]	5.0	3.5	1.5	0.9	0.7	0.2
1.0[e]	0.4-3.0[e]	4.0	1-6	1.2	1.5	2.5	4.0	7.0	14
55[e]	30-90[e]	50[f]	25-400	12	15	20	25	—	30
—	—	—	—	—	—	—	—	40[h]	—
<−76	<−76	−170[f]	<−100	−100	−150	−180	−180	−106	−180
100	100	100	90-120	150	150	150	150	130	150
3500[e]	2900-4000[e]	3300[f]	3500-5500	4400	4400	4400	4400	—	4400
3100	2700-3700[e]	3100[f]	—	4400	4400	4400	4400	—	4400
—	—	—	—	—	—	—	—	4500[h]	—
63	63	60[f]	63-70	68	68	68	68	70	68
250-265	250-265	250-265	[g]	260[k]	260[k]	260[k]	260[k]	—	260[k]
—	—	—	—	—	—	—	—	175[i]	—

[g]Deformation under load for 3 hr at 100 psi and 122 F, or 14 hr at 4000 psi and 22 F, is given as 0.1.
[h]20 in. per min crosshead speed.
[i]264 psi.
[j]66 psi.
[k]Adapted from method of Karrer, Davis and Dieterich, *Ind. & Eng. Chem.*, Vol. 2, No. 30, 1930.

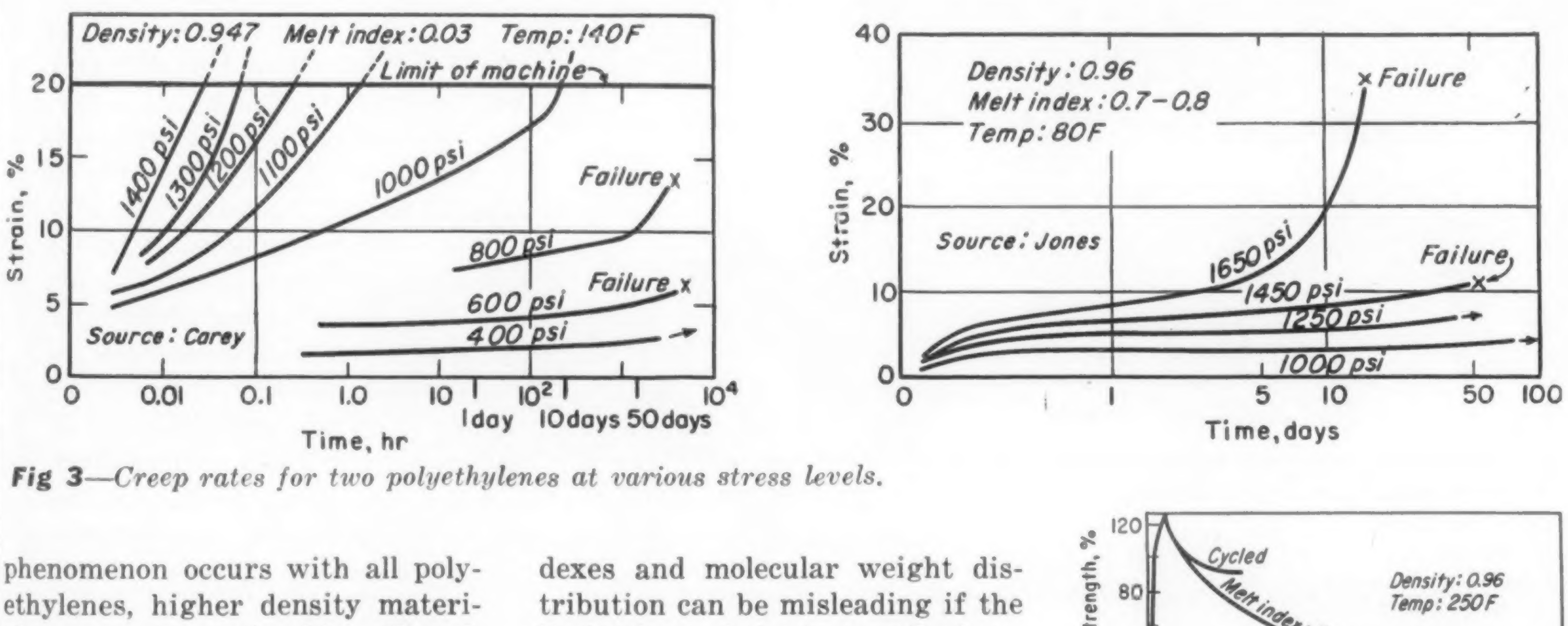


Fig 3—*Creep rates for two polyethylenes at various stress levels.*

phenomenon occurs with all polyethylenes, higher density materials are more noticeably affected, probably because of attempts to use them at higher service temperatures for longer periods of time. The lower the melt index the better the resistance to thermal embrittlement; time having a linear relationship to log melt index.

Environmental stress cracking is a result of exposure of stressed materials to adverse environments such as some chemicals, soaps and detergents. Two factors contribute to the susceptibility of polyethylene to such stress cracking: 1) resistance of the resin itself, and 2) residual stresses in the finished part.

Comparisons of environmental stress cracking resistance of resins of different densities, melt indexes and molecular weight distribution can be misleading if the limitations of the test method are not understood. The widely used Bell Laboratory Bent Strip method consists of bending standard notched samples to standard radii and suspending them in a test fluid (usually Igepal) until failure by cracking. Since the higher density, stiffer materials develop a greater strain in the outer periphery of the bend when bent to the same radius as lower density materials, environmental stress cracking is accelerated in the higher density materials. Although this test often gives fairly reproducible results within a given laboratory, ASTM has found that it shows very poor agreement between laboratories. The ASTM suggests that the test may only safely be used for

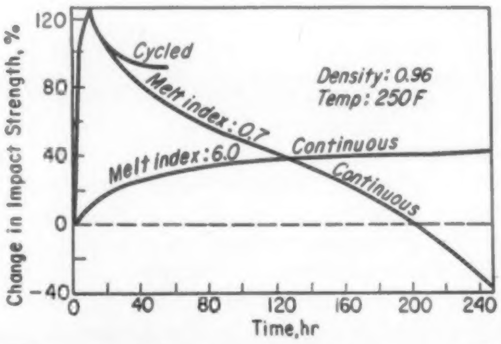


Fig 4—*Effect of continuous and cycled sterilization conditions (250F) on impact strength of 0.96 density polyethylene at two melt indexes. (W. R. Grace & Co.)*

TABLE 2—ELECTRICAL PROPERTIES OF POLYETHYLENE

Dielectric Strength (1/8 in.), v/mil	
Short Time	480
Step by Step	440
Volume Resistivity, ohm-cm	$>10^{15}$
Dielectric Constant[a]	2.3
Dissipation Factor[a]	<0.0005
Loss Factor[a]	<0.0012
Arc Resistance, sec	Melts

[a]Frequency range of 60 to 3×10^9 cps.

routine inspection and acceptance tests within a given laboratory, and then preferably for Type I materials only.

Although Igepal has been widely used for this type testing, many other chemicals are stress cracking agents. The most reliable method of determining resistance to stress cracking of a given polyethylene part is to subject that part, in the form in which it is to be used, to the anticipated chemical service environment and then apply stress.

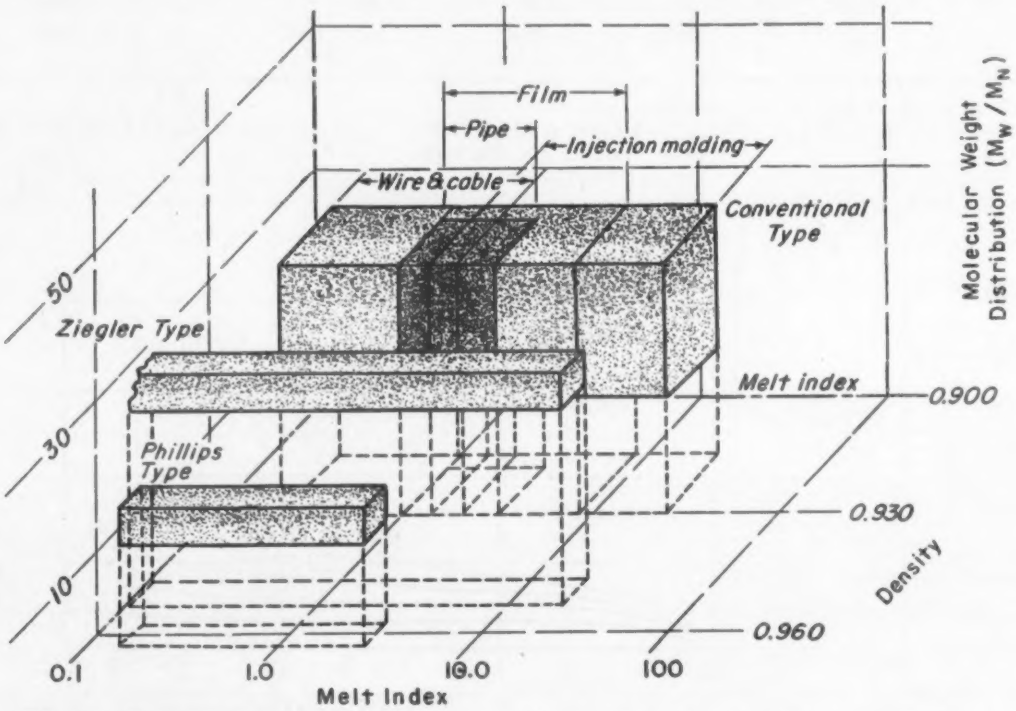
The most effective way of insuring maximum environmental stress cracking resistance of the material itself is to specify, at any given density, the lowest melt index that can be processed to the desired shape. The higher the density, the lower the melt index required.

Other means of improving stress cracking resistance include 1) thoroughly homogenizing 5 to 10% polyisobutylene or butyl rubber with the polyethylene (which also lowers modulus and tensile strength), and 2) using either an irradiationally or chemically crosslinked material.

Effect of sterilization

The "boilability" of Type II and III polyethylenes has resulted in use of the material for sterilizable products. The softening points given in Table 1 indicate only that the materials can withstand sterilization temperatures for short times; however, the effects of long-term exposure to these conditions have also been relatively well determined.

Fig 4 shows the effect of such service on Type III polyethylene of 0.96 density and two different melt indexes. Curves indicate percent change in impact strength for 0.7 and 5.0 melt index resins exposed to 250 F sterilization conditions; both materials were tested continuously. The 0.7 melt index material was also tested by cycling from room temperature to 250 F and back (each cycle taking a total of 35 min) until a total of 50 hr of sterilization had been accumulated. In all cases, physical properties indicated no degradation occurred.



***Three dimensional** chart of conventional and high density polyethylenes shows qualitatively where each fits according to the three molecular parameters.* (McGrew)

Molecular Parameters: Guideposts to Properties

Key to the properties of the new polyethylenes is the reduction in length and frequency of side chains on the molecular spine, which permits the molecules to "pack" more closely together. The closer packing provides higher levels of crystallinity, as measured by density. This structure should not be confused with that of isotactic polymers, such as polypropylene, which gain their name from the symmetrically regular (stereospecific) occurrence of the side chains on the molecule. Though the side chains of the new polyethylenes are shorter and less frequent than in low density polyethylene, they are located in a random fashion along the spine.

The importance of three parameters—density, melt index and molecular weight distribution — as an index to the properties of polyethylenes has been well established (see MATERIALS & METHODS, Sept '56, p 94). The accompanying three-dimensional chart shows generally where each of the types of polyethylene fits as described by these three parameters. Because of the difficulty in determining molecular weight distribution accurately and reproducibly for a given material, most materials producers believe that it is too early for this parameter to be used by designers and engineers as a practical guide to selection of a grade of material.

In using melt index (a guide to molecular weight), in conjunction with density, as an indicator of end properties, the engineer should bear in mind that melt index is also an indication of ease of flow. Although lowering the melt index provides desirable properties for many applications, it may be accompanied by increased processing difficulties.

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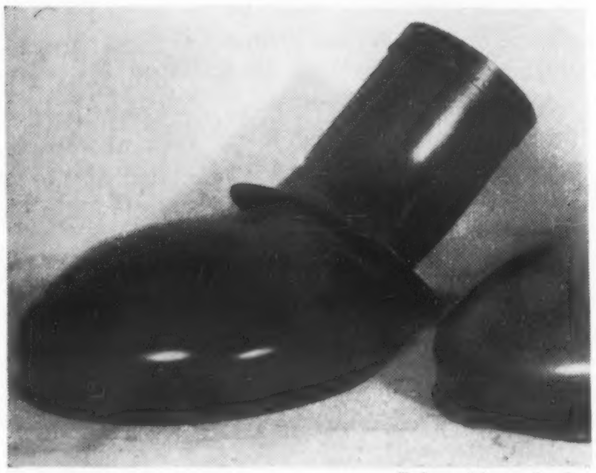
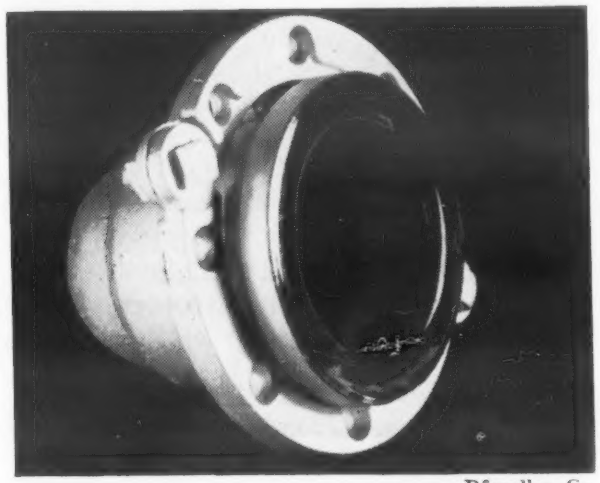
Acknowledgments for assistance in preparing this article will be given next month at the end of Part 2.

Armco Steel Corp.
Sanitary ware

Porcelain Enamel Institute
Electrical components



Solar Aircraft Co.
Engine parts



Pfaudler Co.
Processing equipment

Porcelain Enamel Institute
Appliances

Materials
in Design Engineering

Manual No. 150
July 1958

Porcelain Enamels and Ceramic Coatings

by Robert J. Fabian,
Associate Editor, Materials in Design Engineering

Porcelain enamels and ceramic coatings are becoming increasingly popular as engineering materials. This article is an up-to-date survey for the engineer and designer on:

- *Major types of coatings available*
- *Their important engineering properties*
- *Principal metals that can be coated*
- *Coating selection and design factors*

Porcelain enamels

Porcelain enamels have long been popular as engineering materials because of their combination of protective and decorative properties. Enamels can be formulated with a wide range of physical and mechanical properties, such as high hardness and excellent resistance to chemicals, corrosion, scratching, abrasion and high temperatures. In addition, they can be formulated in a limitless variety of colors and surface finishes to suit the requirements of any application.

What they are

A porcelain enamel is officially defined as "a substantially vitreous or glassy inorganic coating which is bonded to metal by fusion at a temperature above 800 F." The basic ingredient of all enamels is a glass or frit made up primarily of inorganic chemical compounds, minerals, or salts. To a considerable extent, these materials determine the physical and mechanical properties of the coating. Because of the large number of materials that can be used, the number of formulations that are available literally runs into the thousands.

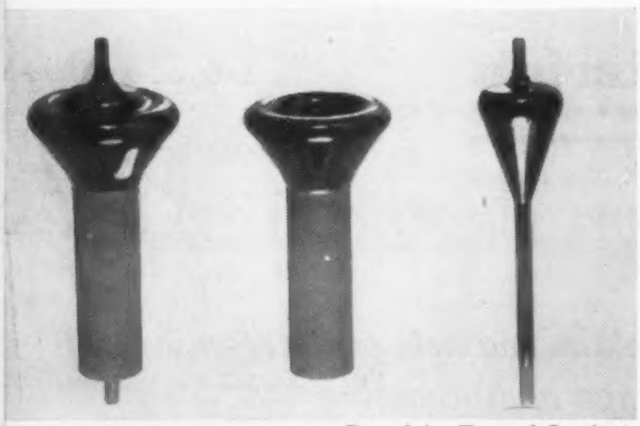
Once a frit has been selected it is charged into a mill, along with water, clay and electrolytes, and ground to form a water suspension (sometimes called enamel slip or milled enamel). The clay acts primarily as a binder and promotes suspension of the frit; the electrolytes (consisting of such materials as sodium nitrite, magnesium carbonate, borax or sodium aluminate) provide proper consistency and set of the slip.

Selecting an enamel

As mentioned, a very large number of enamel formulations (most of them proprietary) are available for different applications. Therefore, in order to narrow the choice down it is absolutely essential to prepare a list of operating requirements. The following points should be considered:

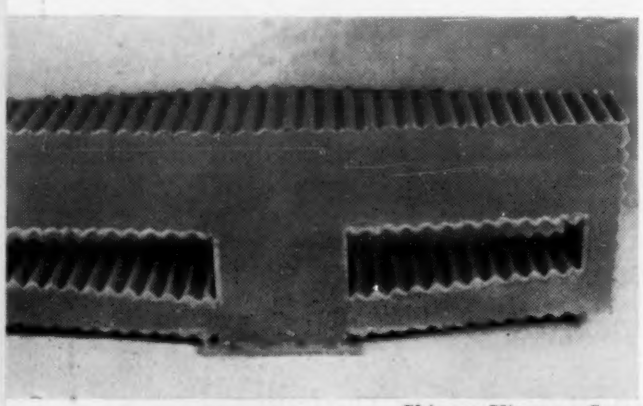
1. To what degree must the enamel resist abrasion, scratching or marring?

Porcelain enamel coatings:



Porcelain Enamel Institute

***Rectifier components** are protected with porcelain enamels to provide a good combination of corrosion resistance and dieletric properties.*



Chicago Vitreous Corp.

***Heat exchanger** is porcelain enameled to protect unalloyed steel from heat and vapor corrosion.*

Barrows Porcelain Enamel Corp.

***Deflecting cones** for petroleum processing equipment use porcelain enamel over stainless steel for protection against heat and oxidation.*

2. Will the coating be subject to any impact?

3. Will the coating be exposed to acids or alkalis? If so, which ones, at what temperature, and to what extent—contact or immersion?

4. Will the enamel be subject to torsion or bending?

5. What is the maximum service temperature expected? Will temperature change be gradual or sudden?

6. Will the coating be subject to weathering or other corrosive conditions?

7. Is the product liable to distort or warp when the enamel is fired or fused? (In such cases a low temperature enamel may be required.)

8. What color and surface finish (matte, semi-matte, or gloss) will be required?

Once these operating requirements have been established the engineer should then consult with a porcelain enameler. Because of the number of enamels that are available it is quite difficult for the engineer, working on his own, to select the best enamel to meet a particular set of operating conditions. The best choice is usually made by mutual agreement between the designer and enameler.

Base metals

Porcelain enamels can be applied to almost any metal that will not melt or volatize below the firing temperature of the coating. In addition to most ferrous metals, enamels can be applied to gold, copper, aluminum (as well as aluminum foil and aluminized steel), titanium, and a number of other nonferrous metals. Even molybdenum and magnesium can be coated if the enamel is fired in an inert atmosphere. Nevertheless, in most applications, porcelain enamels are applied to sheet iron or steel, cast iron, or aluminum.

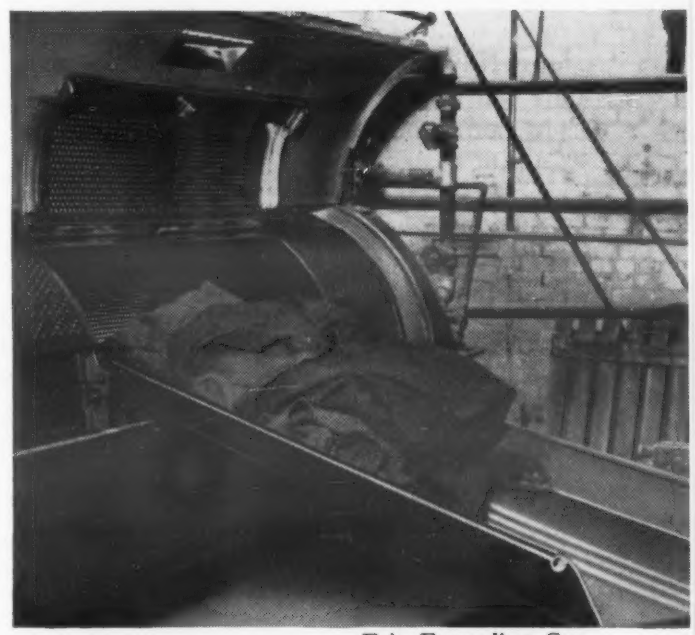
Sheet iron and steel

Porcelain enamels cannot be applied to all ferrous metals and practical use is limited to those metals with a low carbon content, few impurities, and a uniform surface structure. To suit these requirements, special enameling irons have been developed which are highly refined in open hearth furnaces to reduce carbon, manganese, sulfur, phosphorous and silicon content to the practical minimum. These irons are processed in special rolls that impart a tooth-like finish, promoting good enamel adhesion. Enameling irons are available in a general purpose commercial grade and in special deep drawing grades. All of the grades are designed to resist sagging at firing temperatures of 1500 to 1600 F. Plain steels, in contrast,

some typical uses

Westinghouse Electric Corp.

Range top *made from titanium-bearing steel does not require ground coat; it is covered directly with one porcelain enamel cover coat.*



Erie Enameling Co.

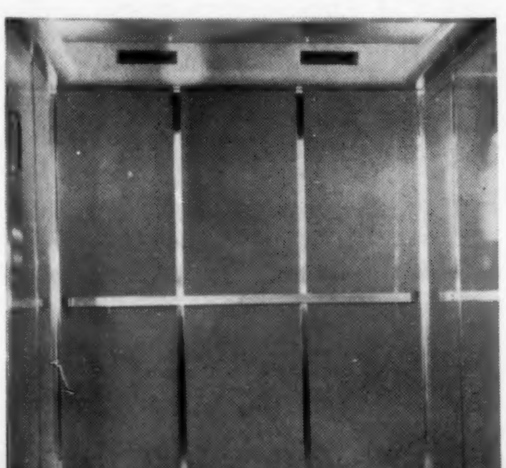
Clothing chute *for dry cleaning equipment is coated with porcelain enamel to resist abrasion.*

Porcelain Enamel Institute

Kitchen appliances *and cabinets protected with porcelain enamels must be decorative and resist abrasion, acids, alkalis and heat.*

Elevator cab *interiors are coated with porcelain enamels to produce a wide range of colors and surface finishes. Enamels withstand abuse of daily service and are easily cleaned.*

(Porcelain Enamel Institute)



have more of a tendency to sag above 1300 F.

In addition to enameling irons, some cold rolled, low carbon steels are suitable for porcelain enameling. In general, these steels must be limited to 0.10 to 0.12% carbon, although up to 0.50% can be tolerated in special cases. Hot rolled steel is not generally suitable for enameling.

Because of their carbon and manganese content, the enameling properties of low carbon steels are usually not as good as those of enameling irons. Low carbon steels have a greater tendency to sag and produce surface defects. For this reason they are often used with enamels that are fired at low temperatures.

Another type of steel known as titanium enameling steel is also available. Properties of this steel are discussed under "one-coat enamels." Because of its comparatively high cost it is not as widely used as the enameling irons or low carbon steels.

Cast iron

Because of its high carbon content and impurities, cast iron is generally more difficult to enamel than sheet iron. Nevertheless, satisfactory enamels can be produced if chemical composition is held within certain limits. Castings should also have a dense and uniform structure and be free of porosity and inclusions. Surfaces should be free of defects and capable of withstanding sandblasting.

Aluminum

Porcelain enameling of aluminum is a recent development which, within a comparatively short period, has become widely used. Because of its light weight, good functional properties and decorative appeal, enameled aluminum is quite popular for transportation and architectural uses.

The successful application of enamels must, of course, take into account the low melting point of aluminum. The firing temperatures used in enameling aluminum may be above the melting point of some alloys. The following alloys are currently recommended for enameling: Sheet—1100, 3003, 6061; extrusions —1100, 3003, 6061, 6062, 6063; castings—43, 356, 344X. Of these, the 6061 alloy is the best for general enameling, especially for architectural applications.

A good deal of enameling has been done on aluminized steel. This combination provides the desirable corrosion resistance of an aluminum surface plus the strength and distortion resistance of a steel core.

Selection of the proper aluminum alloy and gage thickness is extremely important. In general, most of the design considerations that apply to sheet iron also apply to aluminum.

Types of enamels

Ground coats

With the exception of some one-coat enamels and aluminum enamels, most porcelain enamels are applied in two or more coats. The primary functions of the ground or base coat (analogous to a primer in painting) are to: 1) promote adhesion between the base metal and the enamel, 2) seal the metal and prevent evolution of gases during firing, and 3) act as a barrier to prevent any chemical reaction between the base metal and the topcoat(s).

The composition of some ground coats is relatively simple since they do not have to provide as many protective or decorative properties as topcoats. Most ground coats for sheet steels contain about 75 to 85% quartz, feldspar and borax. Feldspar is normally incorporated in the ground coat to extend the firing range and make the enamel more stable during firing. About 0.3 to 0.5% of cobalt oxide, the most important ingredient in promoting adhesion, is normally incorporated in the frit to promote bonding. Other oxides, such as those of nickel and manganese, are commonly used with cobalt oxide to control adhesion and color. In addition, a number of other materials are added to obtain specific physical and mechanical properties. Very often, two or three ground coat enamel frits with somewhat different properties are mixed together to extend the firing range of the enamel and provide greater latitude in processing.

In general, ground coats are applied in thicknesses of 3 to 5 mils by dipping or spraying. (Most porcelain enamels are applied by dipping or spraying. Brush and roller coating are used to a limited extent.) Ground coats for most ferrous surfaces are usually fired at 1450 to 1550 F for 4 to 6 min. However, as noted later, special low temperature enamels are fired at 1280 to 1350 F.

Cover coats

The primary functions of cover coat enamels are to provide protection against expected service conditions and to provide decorative appeal. A large number of enamels are available in a wide range of colors and gloss, with varying degrees of hardness and resistance to abrasion, impact, chemicals, corrosion and heat. In many cases a number of properties can be obtained in just one cover coat. However, in some applications two or more coats will be required to provide a specific group of properties. A cover coat enamel is generally applied thinner than a ground coat enamel. It is also fired at 30 to 40 °F below the melting point of the ground coat to prevent "reboiling."

The largest group of cover coat enamels in use today is formulated with titanium dioxide opacifiers. The main reasons for the popularity of these enamels are that they provide high opacity in thin coatings and they can be formulated with good acid resistance. Zirconium, antimony, fluoride, phosphate, molybdenum and other types of enamels are available where special properties are needed.

Cast iron enamels

Gray iron is ideally suited for use in sanitary products because of its low cost and its ability to be cast into a wide variety of shapes. Because of its comparatively poor appearance and corrosion resistance, the material often requires a protective and decorative coating. Porcelain enamels are ideally suited for this purpose and have long been used on cast irons to provide a decorative and long-lasting product.

Cast iron parts can be covered with just one relatively heavy coat if a dark color can be tolerated. However, for white and pastel colors, both cover and ground are usually necessary. In addition to promoting adhesion and preventing reaction between the metal and cover coats, the ground coat prevents oxidation at high temperatures and seals and smooths surface irregularities.

Cast iron enamels may be more complicated than conventional enamels because of the more severe operating conditions that must be met. They are also applied by different methods and in greater thicknesses. The enamels are produced in a number of grades ranging from hard, acid resistant types, to softer types with lower resistance to acids and abrasion.

Two types of enamels can be used on cast iron.

Wet process enamels are used principally on small and medium size castings and are formulated and

Basic Enamel Terms You Should Know

acid resistance—Using a standard PEI test, enamels are classified into AA, A, and B groups depending on their degree of acid resistance. Class C and D enamels are called non-acid resistant enamels.

alligator hide—A severe case of orange peeling and tearing caused by too fast drying or heavy application of enamel.

anneal—In enameling, the process of heating black iron shapes and raw castings at 1200 to 1600 F to relieve strains, burn off grease and, in some cases, change the structure of the iron to promote better enameling.

bisque—The unfired, dried enamel coating. Bisque coatings must have enough film strength to avoid tearing and still allow for brushing.

black shapes—Raw iron parts as they exist before pickling.

black specking—Dark contaminating particles in a white or light colored cover coat.

boiling—Liberation of gases during firing of topcoat, which causes enamel defects.

brownies—Defects characteristic of white ground coats applied over steel that has not been properly prepared. See also *copperheads.*

brushing—A technique designed to remove the enamel topcoat and reduce overall enamel thickness in highly stressed areas. The thin ground coat remaining after brushing is better able to resist chipping and the effects of contact with adjacent surfaces.

checking—Raised lines on cast iron enamels caused by cracking of the ground coat.

copperheads—Reddish-brown defects in sheet iron ground coats which contain a base layer of oxidized iron and which destroy the continuity of the enamel.

cover coat—The top or last coat as distinguished from the first or ground coat. Some enamels are one-coat enamels, thus serving as ground and cover coat simultaneously.

cracking—The breaking of bisque enamels which usually produces tearing in the fired enamel. Breaking can be caused by rough handling of the bisque or by low dry film strength.

crackled enamel—An enamel with a novel patterned surface obtained by special application and handling.

crawling—A condition whereby topcoat forms into balls or islands during firing exposing ground coat. May be caused by too heavy application, improper drying conditions, or too finely ground enamel.

crazing—Almost invisible cracking extending down to base metal. Not to be confused with *hairlines.*

curtains—Darkened areas in the ground coat, presumably caused by boiling and blistering during firing. Sometimes called *loops* or *looping.*

drain lines—Pattern lines in the surface of fired enamel generally caused by irregular draining action.

dredging—Application of enamel powder to the hot casting in dry process enameling.

dry process enamels—Special enamels developed for finishing comparatively large cast iron parts.

eggshell finish—A matte surface texture.

enameling iron—Very low carbon steel or open hearth iron developed especially for enameling.

firing marks—Tiny indentations similar to pinholes which are caused either by firing supports or by excessive firing temperatures or firing times.

fish scale—Half-moon-shaped particles that pop off the surface of a ground coat. Also refers to holes left in surface. Condition may occur a considerable time after firing.

frit—Basic ingredient of porcelain enamels. Consists primarily of inorganic oxides, minerals, fluorides or salts.

graining—Process of applying an enamel finish that resembles a wood grain.

ground coat—A coating that is especially designed to promote adhesion and is applied directly to the base metal.

hairlines—Fine line defects produced by the ground coat showing through the topcoat. Can result from faulty firing, excessive enamel application, or metal strains. Do not affect serviceability.

jumpers—Bare spots where the enamel has flaked off. Usually caused by dirt, rust, scale or other foreign material.

marbleized—A color grained surface designed to give the appearance of variegated marble.

Mohs hardness—The hardness of a mineral gaged by its ability to scratch or be scratched by one of ten standard minerals: 1) talc, 2) gypsum, 3) calcite, 4) fluoride, 5) apatite, 6) orthodase, 7) quartz, 8) topaz, 9) corundum, 10) diamond. Any mineral in the scale can be scratched by any other mineral with a higher scale number.

mottled ware—One-coat enamelware composed of a series of spots of various shades of gray and designed to give the appearance of coarse granite.

orange peel—Enamel defect characterized by an irregular wavy surface similar to the surface of an orange peel.

rusting—Formation of brown oxide spots during the drying of a wet enamel on a ferrous metal base.

sagging—Referring to enamel: Flow of enamel in waves on surface that is fired in a vertical position. Referring to metal: Any permanent deformation of metal during firing.

shading—A decorative effect produced by spraying a dark enamel over a lighter background.

shiners—A sheet iron defect similar to fish scaling, except that the particles are very minute and the affected surface in reflected light appears as though it were covered with tiny diamonds.

shivering—Chipping of dry process enamels.

shore lines—More or less concentric wavy lines that appear in the surface of fired enamel.

slip—The liquid enamel as it comes from the mill after the wet grinding operation.

specking—Discoloration of a surface caused by the impregnation of foreign particles in the enamel.

stippling—Application of fine drops of enamel to a background enamel with a different color.

tearing—A topcoat defect distinguished by minute breaks, cracks or tears.

For further definitions see ASTM C286-57T, *Definition of Terms Relating to Porcelain Enamel.*

applied much like conventional sheet steel enamels. However, they usually do not contain cobalt oxide, since good adhesion can be obtained by mechanical bonding between the enamel and the rough cast iron surface. In the past, leaded enamels were widely used for cast iron. However, in recent years they have largely been replaced by leadless types containing titanium, zirconium or antimony opacifiers. These enamels are generally fired at 1200 to 1400 F. Firing times are generally longer than with sheet iron parts because of the thicker sections involved.

Dry process enamels are applied in much greater thicknesses than wet process enamels and are usually used on comparatively heavy castings. Ground coats are applied in much the same way as wet process enamels; however cover coats are applied by heating the casting to about 1700F, dusting a dry, fine frit on the surface, and returning the casting to the furnace. The final coating has a high gloss and is quite thick, usually around 40 mils or above.

Low temperature enamels

Probably the most significant development in porcelain enamel in recent years has been low temperature enamels for ferrous sheet. Most of these enamels are designed for firing at 1250 to 1350 F, about 150 to 250 deg lower than conventional enamels. Extra low temperature enamels are also under development for firing in the range of 1000 to 1100 F.

Advantages and limitations—The principal advantage of these enamels is that they reduce the danger of metal warpage, since they can be fired at low temperatures. Consequently, they can often be used over thinner sections, with possible cost savings. It has been reported that the amount of sagging when firing 20 gage metal at 1300 F is comparable to that when firing 16 gage metal at 1500 F. Thus, a 4-gage reduction in metal thickness can sometimes be realized where structural strength is not a factor.

Low temperature enamels require close control over metal preparation, enamel application and firing temperatures. These enamels are generally more expensive than conventional enamels; however, their higher cost is often offset by the use of thinner metals.

Base metals—In general, low temperature enamels can be applied to the same base metals as conventional enamels. An important advantage of the enamels is that they can be applied to so-called non-premium metals. Consequently, these enamels are most frequently applied to low carbon, cold rolled steels, usually 14 gage and lighter.

Metal preparation—Base metals for low temperature enamels are usually prepared by conventional pickling techniques. However, a somewhat heavier nickel flash is required to promote adhesion. Sandblasting alone, without the use of a nickel flash, is not recommended.

Application—Because of their fineness and heavy consistency, low temperature enamel slips are usually applied by spraying, not by dipping. A typical firing cycle for both ground and cover coats is 3 to 5 min at 1340 F. In general, edges and welds are covered better with low temperature enamels, and less burnoff is encountered because the base metal oxidizes less at the lower temperature.

Thickness — Low temperature ground coats are usually applied in thicknesses of 2 to 3 mils. Cover coats range from 3 to 5 mils; however, a minimum of 4 to 4½ mils is usually required to produce good color reproducibility.

Color and gloss—Low temperature enamels generally look the same as conventional enamels. With few exceptions, low temperature enamels are available in a wide range of strong and semi-pastel colors and in gloss or matte finishes. In some cases it appears that color stability may be better than in conventional enamels. Most low temperature frits are titania-opacified.

Acid and alkali resistance—In general, low temperature enamels have poorer acid and alkali resistance than conventional enamels. Enamels can be formulated with Class A acid resistance, but Class AA resistance cannot be attained. However, chemical resistance of the best low temperature enamels is equivalent to that of most conventional enamels and is highly satisfactory for most applications.

Other properties—Adhesion of low temperature enamels is about the same as that of conventional enamels. Compared to conventional enamels, low temperature enamels have poorer resistance to abrasion, scratching, and thermal shock; equal resistance to impact and weathering; and equal or better resistance to torsion and chipping.

Extra low temperature enamels—In addition to the low (1250 to 1350) temperature enamels described above, much research has been devoted to enamels that can be fired as low as 1000 to 1100 F. These enamels are generally lead-bearing. Fired enamels somewhat resemble organic coatings in appearance and, because of their thinness, can be applied to surfaces originally designed for organic coatings.

Some problems of adhesion exist; however, the enamels have better acid resistance than the enamels fired at 1250 to 1350 F. Both Class A and AA acid resistance can be obtained. Alkali resistance also appears to be quite good.

The extra low temperature enamels have a uniform finish which, however, is not as smooth or as opaque as that of conventional enamels. Abrasion and scratch resistance is not as good as for conventional enamels but is much superior to that of organic coatings.

Uses—Some of the products on which low temperature enamels can be used include small appliances, architectural panels and structures, signs, ventilating hoods, prefabricated clothes closets and bathrooms, etc. Some discretion is necessary where high thermal, chemical and abrasion resistance is required.

Aluminum enamels

Aluminum enamels are used primarily in architectural applications and to a lesser extent in consumer and industrial products. Depending on the kind of protection that is required, they can be applied in one or more coats. In general, the properties of aluminum enamels are quite similar to those of the low temperature (1250-1350 F) enamels for ferrous surfaces described above. However, the similarity ends here, as aluminum enamels are basically composed of lead borosilicate glasses with a high coefficient of expansion and are designed to be fired at much lower temperatures—about 930 to 980 F.

Advantages—The principal advantage of aluminum enamels is that they allow aluminum to be used in a number of applications for which it would not normally be considered. Aluminum is distinguished for its light weight, and when coated with a porcelain enamel it can be provided with a greater variety of decorative finishes and added resistance to chemicals, corrosion and damage.

An important advantage of enameled aluminum compared to enameled steel is that it can be sheared, sawed, and drilled without

causing any damage or corrosion at rough edges. In addition, panels can be welded on the reverse side without marring the coating in any way.

Disadvantages—The principal disadvantage of aluminum enamels is that they require very close control during application. Good base metal preparation is extremely important, and more steps are required than with conventional enamels. In general, enameled aluminum is not as good as enameled steel where high strength, low cost or abrasion resistance are important factors.

Metal preparation—In order to produce a satisfactory coating it is essential that aluminum surfaces be cleaned and made receptive to the enamel. All of the alloys must have an inert layer in order to provide spalling resistance. Since the 1100 and 3003 alloys obtain an oxide layer immediately on contact with air they only have to be cleaned in a solvent or alkaline cleaner before enameling. Other aluminum alloys, however, require special surface treatment to build up an oxide layer. For further processing and design details the reader is referred to *Recommended Processing Methods for Porcelain Enamel on Aluminum Alloys*, published by the Porcelain Enamel Institute.

Thickness—Depending on the degree of protection and the color required, the overall thickness of ground and top coat enamels ranges from 2 to 6 mils. Composition and number of topcoats depends on the alloy used as well as the color and end-use properties required.

Color and gloss—Aluminum enamels can be produced in a large number of colors from light pastels to bold dark colors. Colors are available in finishes from a dull matte to a very high gloss, and in stippled, mottled or rippled textures.

Acid and alkali resistance—In general, the acid and alkali resistance of aluminum enamels is quite good, though not as good as in conventional enamels. White and pastel colors have Class A acid resistance; other colors have Class B resistance. The enamels do not stain, streak or fade when exposed to some alkalis and salt spray.

Other properties—It is claimed that the rigidity of aluminum sheet is increased up to 60% by the application of an aluminum enamel. This factor can permit a reduction in metal thickness in some designs. Resistance to thermal shock has been demonstrated by the ability of panels to withstand quenching in cold water after being heated to 1000 F. The dielectric properties of enamels are also good, on the order of 500 v per mil. Impact resistance of aluminum enamels is quite good.

Uses—Aluminum enamels are primarily used in transportation and architectural applications. Some transportation applications include: railway car interiors, ship bulkheads and paneling, pipe and fittings. Some architectural uses include: curtain walls, panels, tiles, door and window frames, hardware, lighting fixtures and sanitary ware. Other uses: kitchen ware, furniture, signs and displays, and cabinets.

Special one-coat enamels

Because of the cost savings that can be realized, much research has been devoted to finding a way of applying a single coat of porcelain enamel to ferrous metals without the use of a ground coat. In order to meet operating requirements it is obvious that any one-coat system must perform at least as well as a multiple coat system. In general, the problem has been approached in three different ways with varying degrees of success.

Special enamel formulations—In order for these enamels to have any cost or production advantages they must be applicable to conventional enameling irons without requiring any unusual surface treatments. To obtain satisfactory adhesion, one-coat enamels usually require special mill additions which, in some cases, reduce other coating properties to a certain extent. Development of satisfactory one-coat enamels has largely been held back by this factor. With the exception of some special enamels for heaters, light reflectors and some architectural applications, one-coat formulations are not widely used. However, as noted previously, conventional ground coat enamels are sometimes used alone where appearance is not an important factor.

Special surface preparation—This method of producing a one-coat system involves the formation of an adhesion-promoting layer on the metal. Most of the systems developed consist of an etching treatment plus a heavy nickel flash treatment which forms a nonreactive surface and promotes bonding. However, one of the most successful surface treatments developed consists of cleaning the surface of enameling iron or cold rolled steel, chemically converting the surface to a phosphate coating, and then prefiring the coating in a conventional enameling furnace to form an oxide layer about 1 mil thick (as compared to about 3 mils for a conventional ground coat). The phosphate coating controls oxidation during prefiring and produces a smooth and adherent oxide with the proper physical and chemical properties to directly accept a one-coat porcelain enamel of conventional formulation.

A good deal of research has been devoted to this process and it appears to have considerable promise. However, it is still in the experimental stage and difficulties have been encountered; very pure water is required in the rinse stages to prevent surface defects, and very close furnace control is required during prefiring to form a satisfactory oxide film.

Special enameling steels—In addition to the aluminum enamels de-

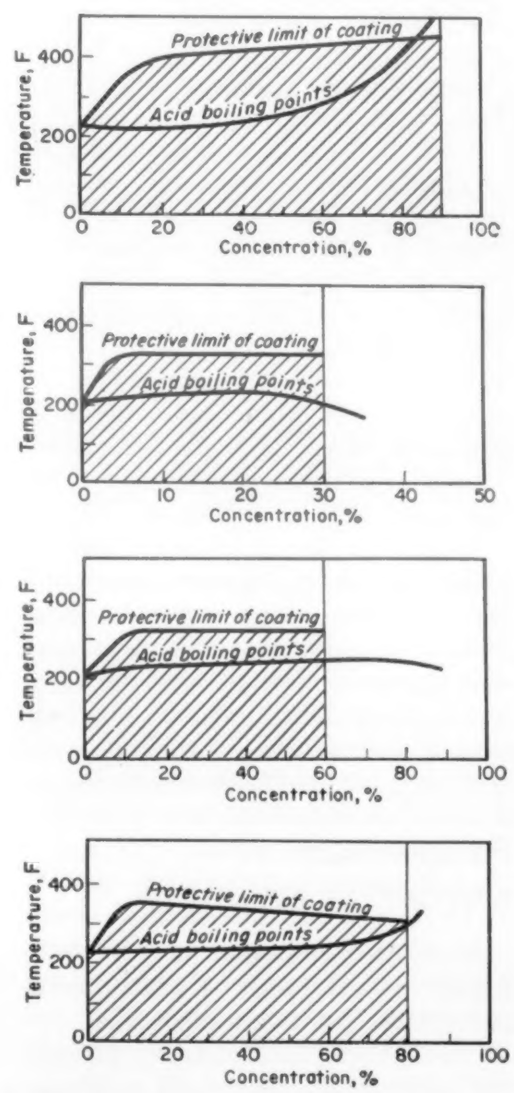


Fig 1—*Resistance of special porcelain enamels to various concentrations of four common acids. From top to bottom: sulfuric acid, hydrochloric acid, nitric acid, and phosphoric acid.*

scribed above, probably the most satisfactory one-coat enamel systems available are those which utilize special enameling steels. Ordinarily, when a cover coat is applied directly to conventional metals, surface defects are produced by the gases given off by the reaction of carbon in the metal and hydrogen in the frit. This condition is prevented in the special one-coat enameling steels by controlling and stabilizing the carbon. A special titanium-bearing killed steel (Ti-Namel) contains titanium (0.20 to 0.50%) which combines with the carbon in the steel, theoretically in the ratio of 4 to 1, to form titanium carbide. This compound is comparatively stable at enameling temperatures. The titanium also combines with and neutralizes the nitrogen, sulfur and hydrogen in the steel.

In general, conventional cover coat enamels can be applied directly to these steels. However, the colors that can be used are limited, enamel white being the most popular shade. Satisfactory white finishes are obtained in thicknesses of 6 to 9 mils, depending on whether interior or exterior use is intended.

Cost of the titanium-bearing steel is higher than conventional enameling irons; however, they are reported to have better resistance to sagging during firing than conventional irons of the same thickness. Some enamels, particularly the antimony-bearing type, produce an excellent bond when fired for 2 to 3 min at about 1500 F. Zirconium-type enamels generally require a firing cycle of 4 to 5 min at 1520 F.

In addition to the titanium-bearing steels, another one-coat enameling steel has been used experimentally. This steel is treated with nickel and decarburized after rolling to form a relatively inert surface which is receptive to a one-coat enamel.

Properties of porcelain enamels

With the exception of low temperature enamels, whose special properties have already been described above, the following properties apply to all single and multiple-coat enamel systems. Because of the large number of enamels and base metals available it is difficult to pinpoint exact properties; however, these data can be used as a good working guide for most product designs. In general, all procelain enamels are resistant to normal atmospheres, oils and neutral organic solvents.

Chemical and corrosion resistance

Water—Porcelain enamels can be used in contact with water up to 150 F; however, water at temperatures over 150 F, especially when pressurized, can be quite damaging to some enamels. Nevertheless, many special formulations are available that provide extreme resistance, as evidenced by their trouble-free use in hot water heaters. Some of these enamels will last for several thousand hours under conditions that would break down galvanized steel in 48 hr.

Acids — Porcelain enamels are available in varying degrees of acid resistance, ranging from fair to excellent. Most enamels have fairly high acid resistance and can be used in contact with mild organic acids, photographic solutions and food products. As shown in Fig 1, special enamels can also be produced that will resist all organic acids and all inorganic acids except hydrofluoric (which dissolves silica, a major component of glass). In all cases, the enameler should be consulted when selecting an acid resistant enamel.

A helpful test for acid resistance is recommended by the Porcelain Enamel Institute; in this test enamels are classed by an AA, A, B, C or D rating, depending on their appearance after exposure to a 10% solution of citric acid for 15 min at 80 F. Another test, which determines resistance to boiling acids, measures the weight loss of enamels after exposure to a boiling 6% solution of citric acid for 2½ hr.

It is difficult to conceive of an enameled product that will not be subject to acid attack in one form or another, whether by the weak acids of citrus fruits or by concentrated mineral acids. On kitchen appliances where prolonged exposure to food acids may be encountered, enamels with an acid resistance of A or better are usually specified.

Alkalis—Until recently, most porcelain enamels possessed limited alkali resistance. However, concurrent with the increased use of detergents and household appliances, many new formulations have been developed that have excellent alkali resistance. Enamels are now available that are highly resistant to such alkalis as boiling 5% sodium pyrophosphate or 2% sodium hydroxide. Formulations can be produced that withstand a pH up to 12 at 212 F.

Weathering—The excellent weathering resistance of porcelain enamels has been demonstrated in a recently completed, 15-year test conducted at four principal locations in the United States. A number of significant observations were made:

1. In all cases where there was good initial coverage and no mechanical damage, the base metal was protected against corrosion for the entire fifteen year testing period.
2. In general, the enamels with the best acid resistance suffered the least gloss deterioration.
3. There was no noticeable fading of Class AA or A acid resistant enamels, nor was there any objectionable fading of Class B enamels. However, almost all Class C and D colored enamels showed very noticeable color changes.

Hardness and abrasion resistance

One of the most distinguishing characteristics and advantages of porcelain enamels is their excellent hardness and abrasion resistance. Depending on formulation, the hardness of enamels ranges from 3½ to 6 on the Mohs scale or about 150 to 560 Knoop. Surfaces are also characterized by their smooth, glassy appearance and low coefficient of friction.

The abrasion resistance of six typical enamel formulations is given in Fig 2. As indicated, the titanium-opacified enamels provide exceptional wear resistance. Poorest abrasion resistance is exhibited by the antimony-opacified, non-acid resistant enamel. Even the ground coat enamel, the antimony-opacified acid resistant enamel and the zirconium-opacified enamel showed a weight loss five to six times greater than the titanium enamels after extensive testing.

In some applications porcelain enamels exhibit greater hardness than many metals. For this reason, enamels are often used in abrasion resistant sanitary ware and in heavy duty industrial applications, such as coal and package chutes, pump pistons, and bucket and screw-type conveyors.

Stiffness

It is not widely appreciated that porcelain enamels can considerably improve the stiffness of metal parts. It has been shown that the stiffness

of enameled parts is a function of the cube of the sum of metal thickness and one-half the enamel thickness. This strengthening effect is shown in Fig 3, which compares the deflection of plain and enameled 22-gage specimens at various loads. Because of these stiffening properties, enamels often permit the use of thinner gage metals with resulting cost and weight savings.

Impact resistance

The impact resistance of porcelain enamels ranges from fair to excellent. Actually, impact resistance is dependent on a number of factors other than enamel formulation. These are: 1) the moduli of elasticity of the metal and the falling body, 2) the radius of curvature of the surface receiving the impact, and 3) the thickness of the metal and the enamel.

Because of the number of variables involved it is difficult to predict accurately the impact resistance of an enameled product. However, a comparison of various enamels and base metal designs can be made by using a standard impact test for porcelain enamels such as ASTM C284-51T.

Typical impact properties of a porcelain enamel are given in Fig 4, which shows the effect of radius of curvature on impact resistance. The impact resistance of surfaces with large curvature is due to the fact that the impact force is distributed over a large area.

Torsion resistance

The torsion resistance of porcelain enamels is important for such products as ranges and refrigerators that are likely to be subject to bending or twisting during shipping or installation. Torsion resistance of an enamel depends on a number of factors, such as number of coats, coating thickness (torsion resistance is generally inversely proportional to thickness), weight of nickel flash coat, etc.

For a thorough evaluation of enamel systems the engineer should use a standard test such as the Porcelain Enamel Institute *Torsion Test for Porcelain Enameled Iron and Steel.* This test measures the number of degrees of twist required to produce failure along the apex of an enameled metal angle.

Color

An almost unlimited variety of colored enamels have been made available because of the increased demands of consumers for colored products. Titanium-opacified enamels, formerly available only in white and light pastels, are now available in several stronger colors. Metallic finishes such as copper, bronze, gold and gunmetal, and even luminescent finishes, are now being produced. A wider variety of speckled finishes are also available.

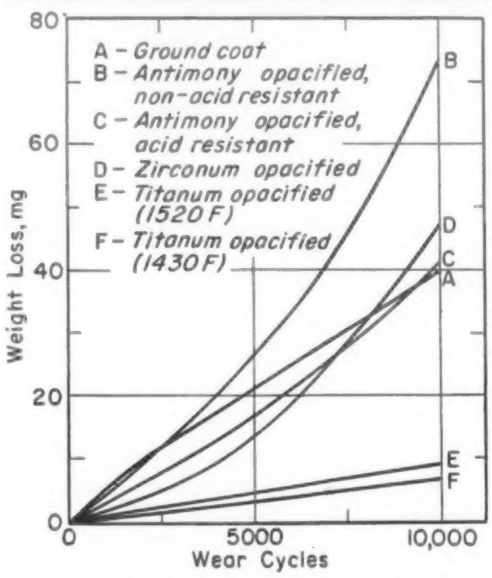


***Fig 2**—Comparative abrasion resistance of six types of porcelain enamels.*

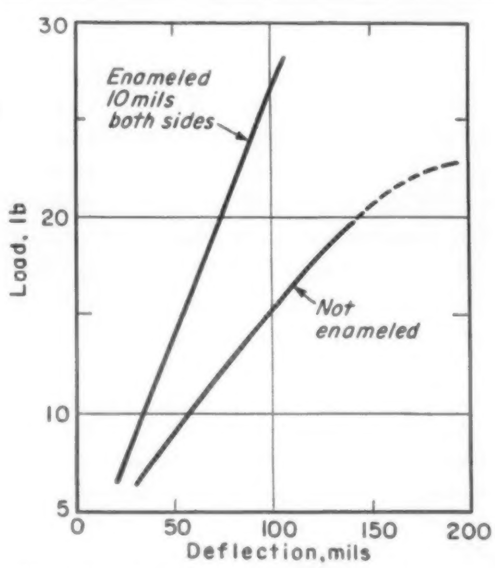


***Fig 3**—Improved stiffness is produced by using heavy porcelain coating on thinner metals.*

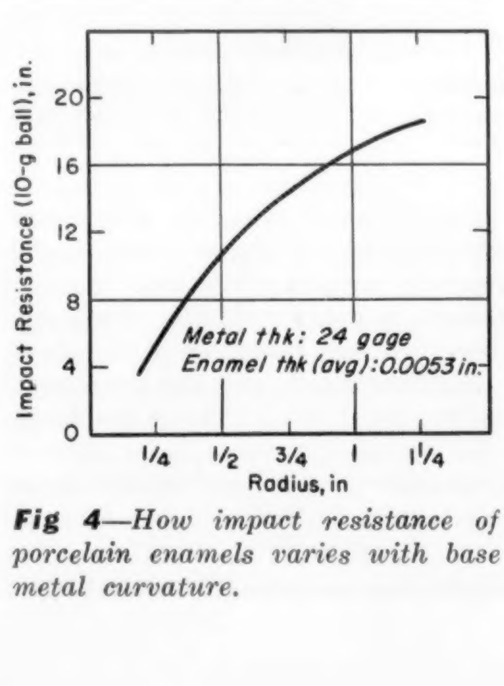


***Fig 4**—How impact resistance of porcelain enamels varies with base metal curvature.*

In general, the strongest and brightest colors, such as the cadmium-selenium reds and oranges and cadmium yellows, are produced in clear glasses. Moderately strong to bright colors can be obtained with semi-opaque antimony and zirconium frits.

Semi-opaque titanium frits are suitable for light to moderately strong colors and are widely used on home appliances. The most stable colors are ivory-yellow, yellow, yellow-brown and blue-green. Pink, gray and other decorator colors are also being used despite the fact that relatively expensive raw materials are sometimes required. The semi-opaque enamels must usually be applied about 20% thicker than conventional enamels.

Opaque titanium frits are suitable chiefly for weak or light pastel colors. Strong colors in opaque titanium enamels require such a high proportion of pigment that the enamels must be ground finer than usual to prevent speckling, and it is difficult to adjust the working properties of the enamels.

Reflectance

Porcelain enamels are available in varying degrees of reflectance. For lighting fixtures the diffuse reflectance of an enamel should not be less than 0.85. In other applications where light reflectance is not too important the reflectance of white porcelain enamels should not be below 0.65 and is usually 0.75 or higher.

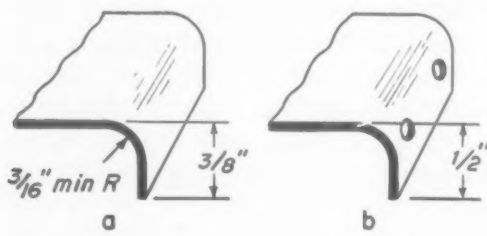
Thermal properties

As described in a later section, special porcelain enamels are available for high temperature applications up to 2100 F. However, unless they are specially formulated, most conventional enamels can only be used at temperatures up to 700 F. A rough rule that has been suggested is that an enamel's maximum operating temperature is about 500°F lower than its firing temperature. In general a conventional enamel can withstand a sudden temperature change of 350°F without failure. Special enamels can withstand temperature changes up to 800°F.

Electrical properties

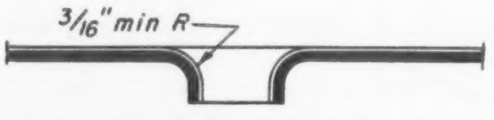
Because of their high inorganic content, porcelain enamels have good dielectric strength, ranging from 500 to 1000 v per mil. Dielectric

Consider These Factors When Designing Enameled Parts



Flange dimensions. *Flanges are usually required on the edges of flat sheets to: 1) stiffen the sheet and prevent warping during firing, 2) round off rough edges and prevent chipping of the enamel, and 3) provide a mounting or fastening surface. Generally, radius of the flange bend should not be less than 3/16 in.; smaller radii create excessive surface tension in the coating, tending to produce thin spots which burn off during firing.*

As shown in a, *all flanges should have a minimum height or width of ⅜ in. If mounting holes are incorporated in the flange, as in* b, *depth should be at least ½ in.*



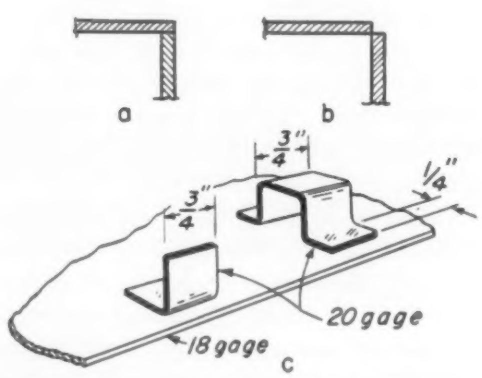
Bolt and screw holes. *Holes for bolts and screws should have a minimum diameter of 5/16 to 3/8 in. to prevent clogging of holes during dip enameling. Also, holes should be made an additional 1/16 to 1/8 in. oversize to allow for edge coating by the enamel. If screw heads are to be recessed as shown, the edges of the bolt holes should be turned down. Radius of the turned down edge should be at least 3/16 in. to provide good enamel adhesion.*

Enamel adjacent to holes can be prevented from chipping by thinning, or brushing away, the topcoat. If this is not possible, nonrusting eyelets, grommets or washers should be used to distribute fastening loads over a wide area.

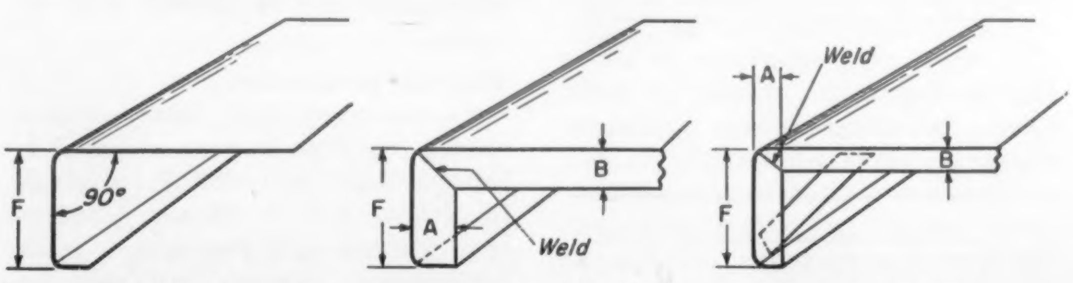
Welded joints. *Certain precautions are necessary in enameling welded joints. The weld must be sound and free from cracks, crevices, bubbles or inclusions to prevent enamel defects. In designing corner welds, joints as in* a *should be avoided, since only one edge of the metal is exposed for welding and a weak joint is liable to be produced. A much better joint with more welding area is provided if the edges are positioned as in* b. *The joint should be peened and rounded over after welding to facilitate enameling.*

Attachments have a tendency to break loose during firing because of unequal expansion. Where attachments are not spot welded to sheet, the space between the spot welds should not be greater than 1 in. For this reason seam welding is preferred where feasible.

As shown in c, *spot welded lugs or clips should be at least two gages lighter than the base sheet. To prevent underfiring in the vicinity of attachments, the double-thickness area of contact should be kept as small as possible. The dimensions shown are typical.*



Porcelain enamel cannot be applied over soft soldered or brazed joints. Riveted joints can only be enameled under ideal conditions, and movable joints, such as hinges, should not be enameled.



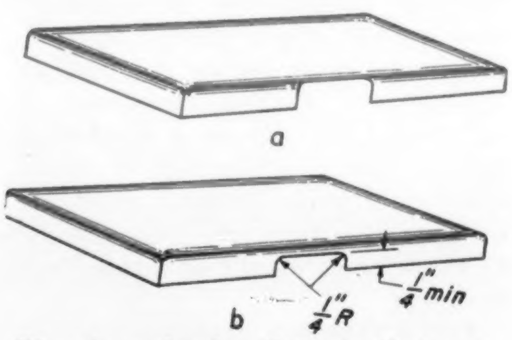
a Weak design. Flange F will change angle in firing

b Good design. A=B=1/3F Flange F is properly supported and will hold angle

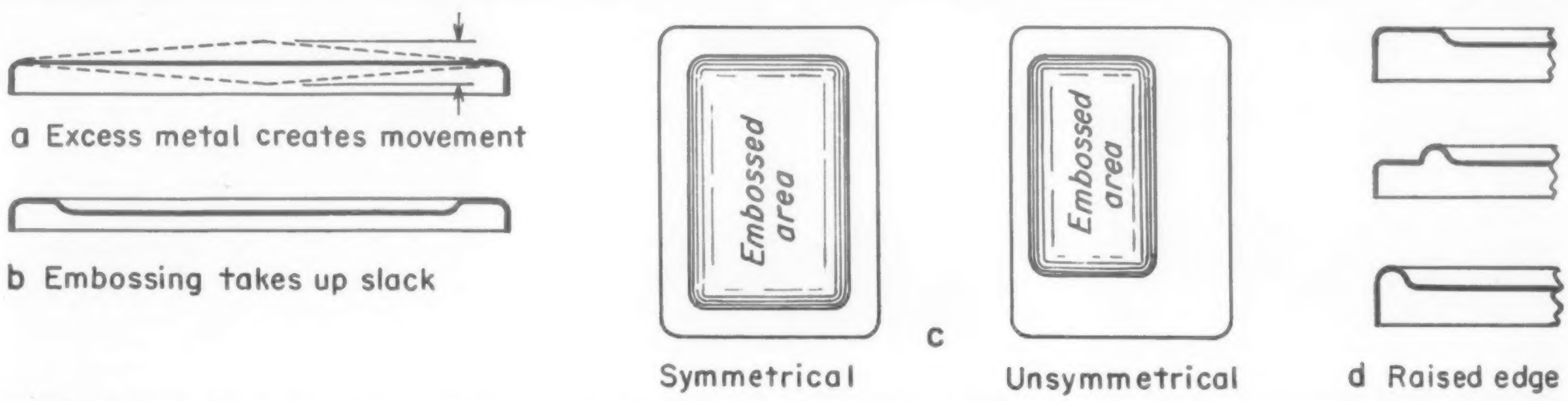
c Alternative method. If A & B are less than 1/3 F additional support can be provided by spot welded strap

Flange stability. *Where a large flange (1 in. or more) is visible in the final assembly, it must usually be kept entirely straight and at an exact angle, usually 90 deg as in* a. *This can be done by providing two end flanges. These end flanges are usually welded together for greater rigidity. However, welding may be dispensed with if the corners are not visible or if the parts to be finished are in black or dark colors. As shown in* b, *end flanges should be equal in width and should be at least one-third the width of the large flange, i.e., A=B=⅓ F.*

On large parts where end flanges do not give proper support they may be braced with a removable strap that is installed just during firing, as in c.

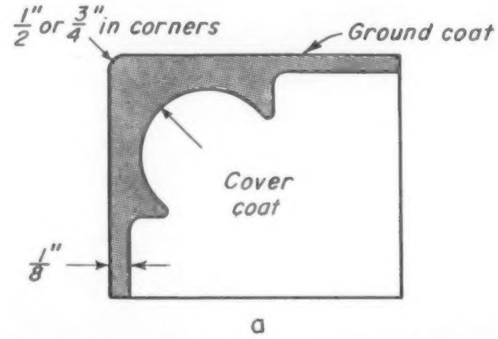


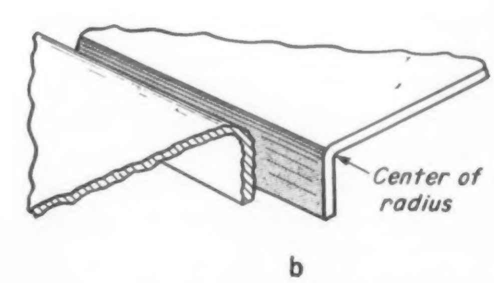
Flange cutouts. *Cutouts that completely interrupt the flange* (a) *should be avoided as they weaken the structure and create stress concentrations at the corners of the cutout which are transmitted to flat surfaces. If cutouts are absolutely required they should have corner radii of at least ¼ in., and at least ¼ in. of metal should be left between the top of the cutout and the face of the piece* (b).



Stiffening. *Large flat areas as in* a *are easily displaced or moved (sometimes called an "oil can effect"). Excess slack in the metal can be taken up by stretching or embossing the metal as in* b. *In all cases embossing should be symmetrical with the outline of the piece* (c), *as unsymmetrical embossing tends to create uneven stresses and distortion.*

Waviness along flat edges can often be overcome by providing raised edges, as in d. *However, care should be taken to work the excess metal out to the edge and not to the center; otherwise, an oil can effect may be produced.*





Brushing. *Chipping or handling damage can sometimes be reduced by brushing, a special technique developed to decrease the thickness of enamel at edges and corners. During brushing (or edging, as it is sometimes called) the finish enamel is removed right down to the base coat. Because of the development of superior enamels, brushing is no longer very common; however, it is still used on some heavy duty products.*

Brushing is essentially a shop operation. Nevertheless, since it can affect the appearance of the product, the designer should be concerned with how it can be controlled to harmonize with the overall design. As shown in a, *the minimum width of brushing should be ⅛ in. Wider brushing should be in multiples of this width. Brushing at corners should be increased to ½ or ¾ in. This increase in width can usually be made decorative, as indicated in the sketch.*

Where a flange contacts another surface, as in b, *it should be brushed over its entire length, as well as over the center of the radius. Brushed areas around holes should have a radius of at least 1/16 in. more than screw heads or washers. Similarly, the edges of cutouts should be brushed to at least ⅛ in.*

strength varies with formulation and operating temperature. The effect of coating thickness is not as great at temperatures above 250 F as it is at room temperature, and consequently actual values should be determined under simulated operating conditions.

Design of porcelain enameled parts

In designing parts to be porcelain enameled, the effect of high firing temperatures must always be kept in mind. A part may be fired many times, and each time it may be subject to sagging or to distortion and stresses due to unequal heating rates.

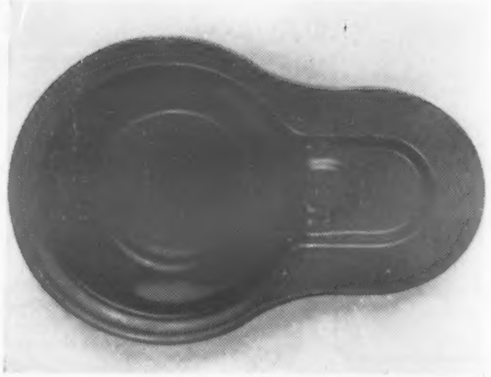
Parts should always be designed so that minimum stress is imposed on the enamel (see design data on p 112). If there is any question about a design a porcelain enameler should be consulted, as he can usually suggest changes that will minimize firing problems and produce a more durable design.

Selecting metal thickness

Selection of the proper metal thickness is extremely important to prevent such defects as warping, sagging, hairlining and chipping. For example, a drawn part containing a large flat area usually tends to be subject to warping because of the creation of unequal stresses in the metal; difficulties may be overcome by switching to a heavier gage.

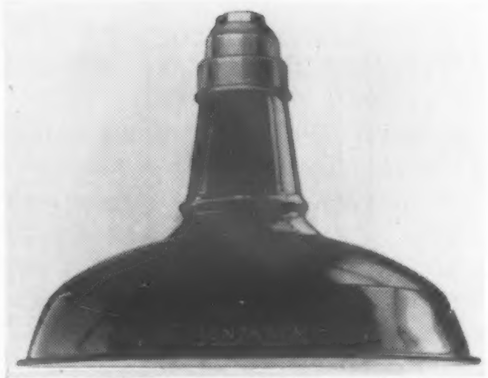
Following is a table of thicknesses that can be used as a *rough* guide for designing medium sized parts that require moderate rigidity and flatness and are to be finished in white or light colors. All areas that are marked with an asterisk should be embossed, flanged or otherwise suitably reinforced. All parts larger than indicated should be made from 18-gage or heavier metal.

Gage	*Width, in.*	*Area, sq ft*
24	6	½
24	12	3*
24	18	5*
22	6	1
22	12	3½
22	18	6*
22	24	8*
20	6	1½
20	12	5
20	18	8*
20	24	10-15*



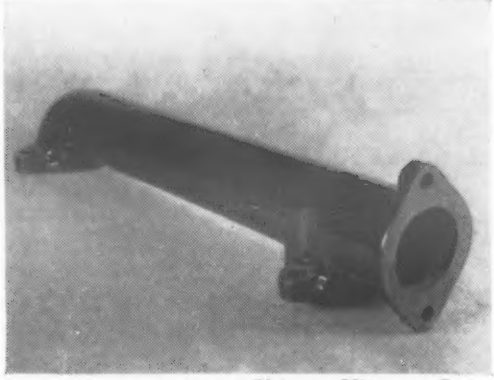
Chicago Vitreous Corp.

Switch plate *for a fractional horsepower motor is enameled on conical portion to resist wearing action of a rapidly moving felt wheel.*



Armco Steel Corp.

Light reflector *made from enameling iron is porcelain enameled to facilitate cleaning and promote long life.*



Chicago Vitreous Corp.

Cast iron exhaust pipe *is protected with porcelain enamel coating against heat and atmospheric corrosion.*

In some cases end-use, rather than application, factors may determine gage thickness. Heavy thicknesses, of course, are required in applications such as hot water storage tanks where hydrostatic pressure is involved. Also, in architectural enamels a heavier gage may be required because of flatness requirements. Small sign pieces may be made as light as 24 or 26 gage, but larger units that are subject to wind pressure may require a stronger metal of 18 or 16 gage. The required degree of rigidity in plumbing ware is usually obtained by using nothing lighter than 14 gage.

Allow for surface build-up

Enamel thickness must be allowed for in the design stage of a product. Though the thickness of enamel in the center of a flat surface may be about 0.015 in., the build-up at edges may run as high as 0.05 in. Consequently, a clearance allowance of about 1/16 in. must be allowed at edges.

Even greater clearances are often needed. A ⅛-in. clearance should be allowed where parts fit into an enameled corner, since the ground coat has a tendency to accumulate in corners during draining. A similar allowance must be made for excess metal on the inside of welded corners, as the welding metal tends to run through the joint and build up on the inside.

Ceramic coatings

Ceramic coatings received their first real impetus 15 years ago with the successful development of the A-19 coating by the National Bureau of Standards. The original coatings were developed primarily to permit the use of noncritical, low carbon steels for military applications during World War II. Since that time a wide variety of coating formulations for military and commercial applications have been developed.

Ceramic coatings are principally designed to:

1. Protect base metals against oxidation and permit their use at high temperatures. In performing this function ceramic coatings can permit the use of less expensive, noncritical metals, or else raise the temperature limit of premium alloys.
2. Provide a hard and abrasion resistant surface.
3. Protect the base metal against corrosion and certain types of chemical attack.

Any one or all of these functions can be provided by a coating through suitable formulation.

Ceramic coatings can be classified into three broad categories, each distinguished for a special group of properties: 1) mixtures of porcelain enamel frits and refractory oxides, 2) refractory oxide coatings, and 3) cermet coatings. The last type is not discussed in detail in this manual (see box, p 116).

Enamel-refractory oxide mixtures

Most ceramic coatings in use today are largely made up of special high temperature porcelain enamel frits plus one or more refractory oxides such as aluminum oxide, chromium oxide, titanium oxide, cerium oxide, etc. Following are the principal coatings in this category that are available to the designer.

NBS A-19

The A-19 coating is the first successful one developed by NBS for protecting noncritical steels against oxidation at high temperatures. The coating is still being used today. It consists largely of oxides of silicon, aluminum, boron, calcium, sodium and potassium, plus calcined alumina, enameler's clay, citric acid crystals and water. The coating is primarily intended for one-coat application on low carbon steels and high temperature austenitic alloys.

In general, metals must be more deeply etched than when using conventional porcelain enamels. Sandblasting is recommended where feasible, but satisfactory adhesion can be obtained by pickling. Grease must be completely removed prior to pickling. Also, a nickel flash should be used after sandblasting.

The A-19 coating is usually applied in thicknesses of 2 to 3 mils. Thicknesses greater than 3 mils can be used, but heavier applications reduce resistance to thermal shock, blistering and chipping. The coatings can be applied by spraying, but parts requiring an interior coating must usually be dipped.

Firing temperature on ordinary steels is 1550-1600 F. Time of firing varies with metal thickness, size and shape of the piece, and the furnace used. A typical schedule for simple 18-gage steel parts is 4 to 5 min.

The operating temperature of low carbon steel parts coated with A-19

is usually limited to below 1250 F because the base metal rapidly loses strength above this temperature. When used on high temperature austenitic alloys the coating affords protection at temperatures up to 1550 F. Military specifications state that protection of base metals against oxidation must be such that a 2½ x 3-in., 18-gage specimen of enameling iron shall not gain more than 0.03 gm in weight after 48 hr at 1200 F. Also, it is specified that 18-gage tubes 6 in. long x 2½ in. in dia must withstand five quenches from 1200 F without visible damage.

NBS A-31

In properties and composition the A-31 system is quite similar to the A-19 coating. Because it must be applied in two coats it is not widely used except for specialized applications.

The A-31 system consists of an A-19 ground coat applied in 2 to 3 mils, followed by a 2 to 3-mil A-20 topcoat. The A-20 topcoat is quite similar in composition to the A-19 ground coat. In general, the A-31 coating is limited to steels with a carbon content of less 0.15%.

NBS A-417

The A-417 coating was quite popular at one time but has been largely supplanted by the A-418 coating. Actually, there is very little difference between the two coatings except that the A-418 formulation does not contain any beryllium oxide. Some objections were raised to the A-417 coating because of the hazards of using beryllium oxide. However, the

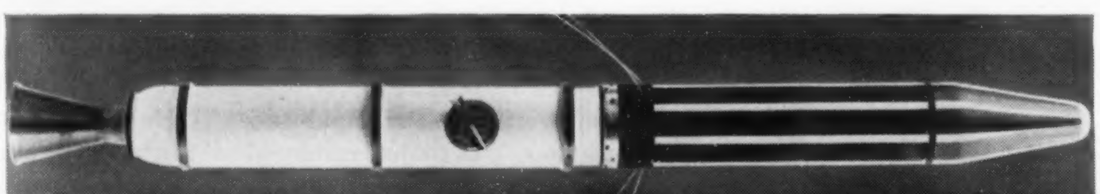
Ceramic coatings: some typical uses

Ryan Aeronautical Co.

Engine exhaust *system is coated with NBS A-417 ceramic coating to protect base metals against high temperature oxidation.*

Solar Aircraft Co.

Afterburner shroud *is provided with reflective ceramic coating on interior and emissive coating on exterior to reduce operating temperatures.*



Norton Co.

Explorer satellite *is coated with eight ¼-in. aluminum oxide stripes to control temperature inside instrumentation package.*

Bearings *can be coated with special ceramic coatings which have smooth, low friction, abrasion resistant surfaces.*

beryllium oxide in the A-417 coating is chemically combined in the frit and there have been no reports of any deleterious effects after coating thousands of parts.

NBS A-418

The A-418 coating, along with the NBS A-19 coating and other proprietary coatings, is one of the most popular enamel-refractory oxide coatings in use today. The coating frit is made up of oxides of silicon, boron, barium, calcium, zinc, aluminum and zirconium, and is mixed with chromic oxide, enameler's clay and water.

The coating is not recommended for low carbon steels, since the high firing temperature required (1875 F for 3 to 10 min) tends to distort and warp all but the simplest shapes. However, the coating performs extremely well on heat resisting steels, and has been used with good results on Inconel, Inconel X, Nimonic 75, HS-21, S-816, and 18-8, 19-9 and 25-20 stainless steels. The coating considerably extends the life of these alloys at operating temperatures up to 1750 F. It has also been successfully used with other alloys; however, final selection should be checked with the enameler.

Base metal pretreatment usually consists of a light sandblasting. Final coating thickness is about 1 to 2 mils.

NBS N-143

The N-143 coating was developed for use in nuclear reactors and consists of an alkali- and boron-free barium-beryllium silicate frit, plus cerium oxide, enameler's clay and water. It was designed for alloys such as 310 stainless steel, Nichrome V and Inconel, and affords appreciable protection against oxidation at temperatures up to 2050 F. An outstanding feature is its very low absorption coefficient for thermal neutrons.

Proprietary coatings

In addition to the above NBS coatings, a wide variety of proprietary enamel-refractory oxide ceramic coatings are also available from enamelers. Some of these proprietary coatings are just variations of the basic NBS coatings: however, most of them are unique formulations which are designed to improve the oxidation resistance of base metals at temperatures up to 2100 F. When required, they can be made to provide varying degrees of resistance to abrasion, corrosion and galling. Depending on formulation, a wide range of base metals and operating conditions can be accommodated. The following coatings are just typical of those that are available.

1. For low carbon and low alloy steels. These coatings are fired at 1600 F and are designed to improve the oxidation and corrosion resistance of metals at temperatures up to 1400 F. They have a gray, matte appearance and are intended for use on such equipment as space heaters, heat exchangers, combustion chambers and exhaust pipes.

2. For 300 and 400 series stainless steels. Several formulations are available for protecting these metals. One of the principal formulations is fired at 1700 F and can be used on all of the 300 and 400 series stainless steels except the free-machining grades and those containing more than 0.5% carbon. It can also be used on nickel and cobalt-base alloys that contain at least 10% chromium, provided they do not contain 15% or more of molybdenum or tungsten. The coating has extended the service life of parts 400% when used at operating temperatures up to 1800 F. Principal uses have been for turbojet combustion chamber liners, tail cones and afterburner liners; manifolds and turbo hoods; and industrial furnace baffles, combustion chambers, electric heating elements and bellows. Modified formulations are also available for use on parts subject to unusual corrosive or abrasive attack at temperatures up to 2000 F.

3. For aluminum. Several proprietary formulations have been developed in the past year for all of the

Cermet Coatings

In contrast to porcelain enamels and ceramic coatings, which are made up primarily of inorganic oxides, cermet coatings consist essentially of a combination of metallic and nonmetallic elements which may or may not be diffusion-bonded to the base metal. Cermet coatings can often provide certain design and cost advantages not obtainable in porcelain enamels or ceramic coatings. Following is a brief summary of the principal cermet coatings:

Tungsten carbide — Extremely hard and wear resistant layers of tungsten carbide can be deposited on metal surfaces with a specially constructed gun. Coatings range in thickness from 2 to 10 mils and have an overall hardness of about 1350 Vickers. Practically all metals can be coated, and since base metal temperature seldom exceeds 400 F, changes in mechanical properties are negligible. (For further information see "Try Flame-Plated Coatings Where Service is Severe," MATERIALS & METHODS, Feb '56.)

Chromium carbide—Chromizing can be used to produce a hard and wear resistant chromium carbide surface on low carbon steels, many alloy steels, high chromium and stainless steels, cast iron and iron powder parts. (For further information see Manual No. 134, "Hard Coatings and Surfaces for Metals," MATERIALS & METHODS, Jan '57.)

Silicon carbide—Silicon carbide coatings are used primarily to improve the erosion resistance of graphite parts at high temperatures. Coatings can be formed in thicknesses of 2 to 30 mils and are more resistant to oxidation than pure carbon. These coatings can be used up to 4000 F and are highly resistant to acids and alkalis. Knoop hardness is 2500 at 100-gm test load.

Aluminum-ceramic coatings—These coatings are comparatively new and consist essentially of a mixture of aluminum alloy powders and ceramic frits. They are applied to carbon steels, low alloys and cast iron by spraying or dipping. The coatings are diffusion-bonded to the base metal after firing between 1235 and 1600 F, and have a metallic finish. They are quite inert at temperatures up to 1100 to 1200 F, and have very high resistance to thermal shock and impact. They can be applied in thicknesses up to 50 mils; however, adequate long term protection is generally provided by 3 to 4 mils.

Nitriding—Although it is not usually thought of as such, a nitrided case is essentially a cermet. Nitriding, which is limited to certain grades of steel, forms an extremely hard case (1000 DPN) which retains hardness up to 1100 F and is not subject to fatigue. (For further information see Manual No. 98, "Surface Hardening of Steels and Irons," MATERIALS & METHODS, Oct '53.)

standard aluminum alloys as well as some of the high strength alloys. The coatings consist primarily of a low melting glass, plus refractory oxides and fluxing agents.

Normally, wrought aluminum alloys melt at temperatures between 1250 and 1350 F and begin to soften at considerably lower temperatures. However, aluminum surfaces treated with the new coatings have been reported to withstand temperatures of 1500 to 1550 F before softening occurs.

The coatings are usually applied in thicknesses of 0.0015 in. either on one or both sides of the metal. They are said to have excellent adhesion and good resistance to thermal shock, flame impingement and impact. Resistance to chemicals and abrasion, however, is limited, and the coatings are said to produce a 10 to 12% reduction in the tensile strength of the base metal as a result of the firing operation.

4. For titanium. These coatings are intended primarily for titanium aircraft parts operating at about 1500 F. Coatings are fired at 1800 F and have a glossy blue appearance.

5. For thin-gage metals. These coatings are especially designed for metals from 1 to 10 mils thick operating at temperatures up to 1750 F. They are used largely on the 300 series stainless steels, but can be adapted for the 400 series stainless steel and the superalloys. Principal uses have been for afterburner insulating blankets and high temperature solenoid coil insulators.

6. For extra high temperatures. Special enamel-refractory oxide coatings are available for use up to 2100 F. These coatings require special surface processing and are fired at 1900 F. They can be applied to all of the stainless steels with the exception of the free-machining grades. They are recommended for use on alloys containing 45% of the combination of chromium, cobalt and nickel (with a minimum of 10% chromium).

7. For resistance to galling. These coatings are designed to provide low friction, prevent galling, and minimize fretting corrosion at temperatures from 800 to 1650 F. Depending on formulation, a wide variety of base metals can be coated including those described in 2, above, all of the ferrous alloys, the nickel and cobalt-base alloys, the cupro-nickels and pure copper.

Refractory oxides

For many years the use of pure unbonded refractory oxides as coating materials was held back by the lack of suitable application methods and equipment. Recently, however, a number of successful techniques have been developed for applying these materials. The most important methods are flame spraying (for materials in rod or powder form), Flame-Plating, and solution ceramic techniques. These methods have been used to produce a wide range of refractory oxide coatings, including: aluminum oxide, zirconium oxide, zirconium silicate, aluminum silicate, titanium dioxide, iron titanate, cerium oxide and magnesium oxide. The properties of a number of these materials are summarized in the accompanying table. To date, the aluminum oxide, zirconium oxide and zirconium silicate coatings have proved to be the most successful.

Aluminum oxide (alumina)

Aluminum oxide coatings can be applied by all three of the methods mentioned above. The coatings are noted principally for their high resistance to wear and abrasion; however, they also provide good thermal insulation and high resistance to oxidation. Because of the low application temperatures involved during spraying, they can be applied to almost every ferrous and nonferrous metal as well as some plastics and other nonmetallic materials.

The excellent abrasion resistance of aluminum oxide coatings at room and elevated temperatures is largely due to their high macrohardness, which is equivalent to Rockwell C45. Despite the fact that the coatings are secured by a mechanical bond, adhesion and impact strength are reported to be quite good. A 1/16-in. thick sheet with a 0.010-in. coating can be bent 45 deg with no evidence of failure.

Aluminum oxide coatings are usu-

PROPERTIES OF REFRACTORY OXIDE CERAMIC COATINGS[a]

Type➡	Aluminum Oxide	Zirconium Oxide	Zirconium Silicate	Aluminum Silicate	Titanium Dioxide	50% Iron Titanate: 50% Gamma Aluminum	Iron Titanate	Rare Earths (50% cerium oxide)
APPLICATION PROPERTIES								
Deposition Rate, sq ft/hr/10 mils	15-16	4-10	—	16	10	10	10	8
Thickness Range, mils	5-50[b]	5-50[c]	5-50	—	—	—	—	—
Finish After Polishing, μin. rms	2-50[d]	15-50[d]	30-50	52-77	6-43	16-38	7-52	32-48
THERMAL PROPERTIES								
Melting Point, F	3600-3700	4500-4600	3000	3200	3200	2500	2500	—
Coef of Ther Exp, 10^{-6} per °F	4.0-4.3[d]	5.4-6.4[d]	4.2	2.5	4	—	—	5
Ther Cond, Btu/hr/sq ft/°F/in.	19-20	7-8	15	25	45	—	—	20
Shock Resistance	Good	Very good	Good	—	—	—	—	—
OTHER PROPERTIES								
Dielectric Strength, v/mil	200	100[e]	Nonconductive	—	Conductive	Conductive	Conductive	—
Vickers Hardness (DPH, 25-gm load)	1400	400	1000 Knoop	650	1500	800	700	600
Porosity, %	8-12	8-12	8-12	—	—	—	—	—
Density, lb/cu in.	0.12	0.19	0.14	—	—	—	—	—

[a]Properties generally apply to flame sprayed coatings. Properties of solution coatings may differ somewhat.
[b]Thicknesses up to 0.125 in. can be produced for special applications.
[c]Thicknesses over 0.10 in. can be produced for special applications.
[d]Varies with method of application.
[e]Nonconductive at room temperature; conductivity increases rapidly above 2190 F.

ally used in thicknesses of 0.001 to 0.050 in. and occasionally in thicknesses up to 0.125 in. Surface finish is often an important factor, since the coatings are frequently used in bearing applications. The as-coated finish ranges upward from 125 μin. rms depending on the application method; however, finishes of 1 to 2 μin. rms after a fine diamond lap have been reported.

The coatings are very useful for high temperature applications since they do not oxidize or melt at temperatures up to 3600 F. Resistance to thermal shock is also excellent. The coatings have a coefficient of thermal expansion of 4.0-4.3 x 10^{-6} per °F over a temperature range of 100 to 2100 F. Thermal conductivity is about 19 Btu/hr/sq ft/°F/in. at 1000 F.

In general, the coatings are not attacked by common acid or salt solutions, by oxidizing or reducing atmospheres, or by many low temperature molten liquids. They are attacked by hydrofluoric acid and hot sodium hydroxide, and may be attacked by many molten salts and metal oxides. Porosity of flame sprayed coatings ranges from 8 to 12%, whereas porosity of Flame-Plated coatings is claimed to be less than 1%.

Because of their excellent combination of properties, aluminum oxide coatings can be used in a variety of applications requiring varying degrees of resistance to abrasion, heat or corrosion. Actual and potential applications include: seals operating under heat and in corrosive atmospheres, thrust bearings, pump plungers, aircraft and missile engine parts, and insulation for electronic components.

Zirconium oxide (zirconia)

In common with aluminum oxide, zirconium oxide coatings can be applied to almost all metals, as well as some nonmetallics. Because of their higher melting point (4500 F), zirconium oxide coatings are more widely used for high temperature applications; however, they are not as hard or as resistant to abrasion as aluminum oxide coatings.

Zirconia coatings are usually applied by flame spraying. They can also be applied by solution ceramic techniques, but to date this method of application has not been widely used. They cannot be applied by Flame-Plating. The coatings can be applied in thicknesses from 0.005 to 0.050 in., but are frequently used in a thickness of about 0.010 in. to obtain an adequate compromise of oxidation resistance, refractory properties and resistance to impact. Thicknesses over 0.10 in. can be applied for special applications.

As the table indicates, zirconium oxide has somewhat higher thermal expansion than other refractory oxide coatings. Thermal conductivity, however, is quite low—on the order of 8 Btu/hr/sq ft/°F/in. at 1000 to 2000 F. The coating is not electrically conductive at room temperature, but conductivity begins to increase rapidly above 2190 F. So far, the coatings have been used principally to protect high temperature missile and rocket parts against oxidation and corrosion and to provide thermal insulation.

Zirconium silicate

Zirconium silicate coatings are formed during flame spraying through the dissociation or zircon (in rod form) into zirconium oxide and silica. The final coating consists of 65% zirconium oxide and 34% silica.

Many of the properties of zirconium silicate coatings are similar to those of aluminum oxide coatings. Coatings are hard and adherent and can be used up to about 3000 F before the glass phase begins to soften. They have excellent corrosion resistance and are nonconductive.

Impregnated coatings

Quite often the impact and abrasion resistance of flame sprayed ceramic coatings can be improved by impregnation. Phenolics, furane, silicones, epoxy-base formulations, and a variety of other organic and inorganic impregnants have been successfully used. Phenolic and furane impregnants have proved particularly good because of their good physical properties. The heat-cured types of impregnants are preferred, but both catalyzed and air dried types have proved acceptable.

Most impregnants have been used with flame sprayed, powdered aluminum oxide coatings. Coatings impregnated with a baked or catalyzed phenolic have been used on fan blades to improve their resistance to severe abrasive conditions. Also, extra corrosion resistance to specific reagents can be supplied by impregnating the coatings with an appropriate sealer such as a microcrystalline wax. Solid lubricants such as molybdenum disulfide or graphite can also be added to improve friction properties and galling resistance.

Insulating coatings

In most applications refractory oxide ceramic coatings are simply applied over surfaces that have been sandblasted to promote mechanical bonding. However, recent research conducted for the Wright Air Development Center indicates that the useful range of some ceramic coatings may be considerably extended by using some type of reinforcing mechanism. Aluminum oxide and zirconium oxide coatings, as well as other ceramic coatings, have been applied to expanded steel mesh sections which are first seam welded to the base metal. Excellent insulating properties have been obtained, and the reinforced coatings have produced appreciable thermal drops at operating temperatures of 2000 to 3000 F.

In general, brush and spray application of the coatings has not been very successful; best results have been obtained by pressure rolling heavy-bodied, dough-like compositions. Much development work remains to be done on these coatings, and despite promising results it is difficult to say at this early stage if they will prove commercially acceptable.

Acknowledgments

The author would like to express his appreciation for the assistance of personnel and literature from the following organizations in preparing this article:

A. O. Smith Corp.
Armco Steel Corp.
Armour Research Foundation
Bettinger Corp.
Chicago Vitreous Corp.
Continental Coatings Corp.
E. I. du Pont de Nemours & Co., Inc.
Erie Ceramic Arts Co.
Erie Enameling Co.
Ervite Corp.
Ferro Corp.
Flame Ceramics, Inc.
Gulton Industries, Inc.
Ingersoll Products Div., Borg-Warner Corp.
Inland Steel Co.
Kraus Research Laboratories
Lead Industries Assn.
Linde Co.
Marquardt Aircraft Co.
Metallizing Co. of Los Angeles
Metallizing Engineering Co., Inc.
Monarch Aluminum Mfg. Co.
National Bureau of Standards
Norton Co.
Pacific Coast Borax Co.
Parker Rust Proof Co.
Pemco Corp.
Pfaudler Co.
Porcelain Enamel Institute
Ransburg Electro-Coating Corp.
Ryan Aeronautical Co.
Solar Aircraft Co.
Titanium Pigment Corp.
Vikon Tile Corp.
Vitro Mfg. Co.
Wolverine Porcelain Enameling Co.

FILE FACTS

Wrought Magnesium-Thorium and Magnesium-Zirconium Alloys

ASTM Type ➔	HM31X[a]	HM21A-T8[c]	HK31A	—	—	ZK60A-F
COMPOSITION, %	Th 2.5-3.5, Mn 1.2 min	Th 1.5-2.5, Mn 0.35-0.8	Zr 0.4-1, Th 2.5-4	Zn 0.75-1.5, Zr 0.5-1.0	Zn 2.5-4, Zr 0.5-1.0	Zn 4.8-6.2, Zr >0.45
PHYSICAL PROPERTIES						
Density, lb/cu in.	0.0651	0.0640	0.0647	0.064	0.065	0.0659
Melting Temp Range, F	1202-1121	1202-1121	1202-1092	—	—	1175-968
Ther Cond (68 F), Btu/hr/sq ft/°F/ft	60	80	66	73	73	67
Coef of Ther Exp (68-400 F), per °F	10.5×10^{-6}	14.5×10^{-6}	14.5×10^{-6}	15.1×10^{-6}	15.1×10^{-6}	14.5×10^{-6}
Spec Ht, Btu/lb/°F	0.245	0.245	0.245	0.245	0.245	0.245
Elec Res (68 F), microhm-cm	6.6	5.1	6.4	5.8	5.8	6.0
MECHANICAL PROPERTIES[d]						
Mod of Elast in Tension, psi	6.5×10^6	6.5×10^6	6.5×10^6	6.5×10^6	6.5×10^6	6.5×10^6
Ten Str, 10C0 psi	—, —, 37	34, 33, —	37[c], —, —	36-45, —, 15-20	40-45, 45-49, 47-51	—, 49, 49[a]-52[b]
Yld Str (0.1% set), 1000 psi	—, —, 26	25, 20, —	29, —, —	24-27, —, 27-32	27-31, 31-33, 33-38	—, 38, 37[a]-42[b]
Elong (in 2 in.), %	—, —, 10	10, 15, —	8, —, —	8-18, —, —	8-18, 12-14, 15-25	—, 13, 13[a]-12[b]
Hardness (Vickers)	—, —, —	—, —, —	55, —, 55	55-75, —, 60-80	60-80, 60-80, 60-80	—, 75, 75
Impact Str (Izod), ft-lb	—, —, —	—, —, —	—, —, —	—, —, —	—, 3-5, 7-9	—, —, —
Fatigue Str, 1000 psi	—, —, —	—, —, —	—, —, —	—, —, 16.8	—, —, 19	—, —, —
Compr Yld Str, 1000 psi	—, —, 15	15, 17, —	23, —, —	—, —, 22-29	—, 20-29, 27-33	—, 28, 25-33
Creep Str (stress to give 0.5% ext in 100 hr), 1000 psi						
400 F	—	13.5	11	—	—	—
500 F	—	9.0	2.0	—	—	—
600 F	—	6.0	—	—	—	—
THERMAL TREATMENT						
Aging Temp, F	—	—	—	—	—	275 (48 hr)
FABRICATING PROPERTIES						
Hot Working Temp, F	650-800	650-800	650-700	500	500	300-500
Machinability (free-cutting brass = 100)	500	500	500	500	500	500
Weldability	Can be welded by inert-gas shielded arc methods and spot welding					Not weldable
CORROSION RESISTANCE	Good resistance to the atmosphere; attacked by salt water					
AVAILABLE FORMS	Extrusions	Sheet, plate, forgings	Sheet, plate	Sheet, extrusions, tubing	Sheet, forgings, extrusions	Extrusions, forgings
USES	High temp (600-850 F) aircraft service, missile components	High temp (600-900 F) aircraft service, missile components	High temp (600-800 F) aircraft service, missile components	Airframe parts, skins, ribs and spars, windows		

[a]As extruded. [b]Heat treated. [c]T8 temper for sheet, T5 temper for forgings.
[d]Mechanical properties given for sheet, forgings and extrusions, in that order.

Prepared with the assistance of Dow Chemical Co. and Magnesium Electron, Inc.

◄ For more information, circle No. 366

FILE FACTS

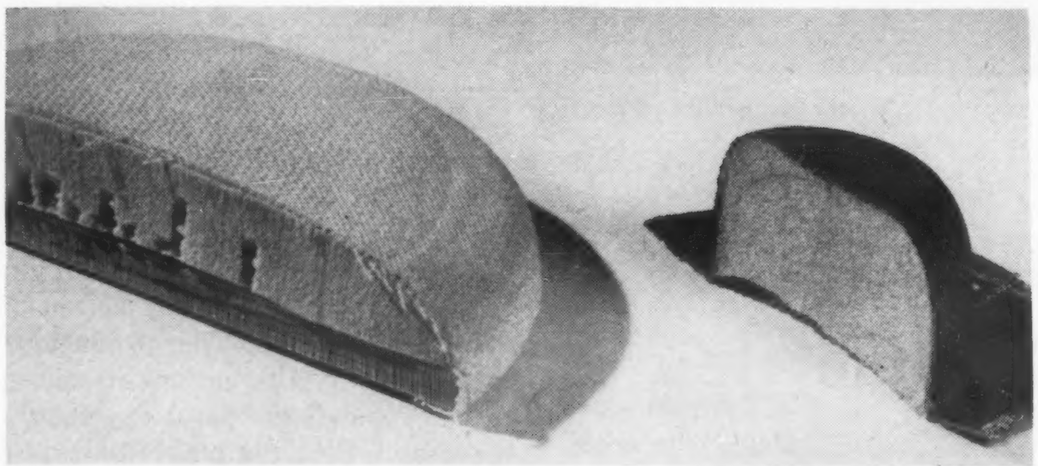
Cast Magnesium-Thorium and Magnesium-Zirconium Alloys

ASTM Type[a] →	EZ33A	HZ32A	ZH62A	ZK51A
COMPOSITION, %	Zn 2.0-3.5, Zr 0.5 max, rare earths 2.5-4	Zn 1.7-2.5, Zr 0.5 min, Th 2.5-4	Zn 4.8-6.2, Zr 0.5 min, Th 1.4-2.2	Zn 3.5-5.5, Zr 0.5-1
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.0659	0.0659	0.0670	—
Melting Temp Range, F	1189-1010	1198-1026	1165-960	1185-1020
Ther Cond (68 F), Btu/hr/sq ft/°F/ft	58	60	65	65
Coef of Ther Exp (68-400 F), per °F	14.9×10^{-6}	14.8×10^{-6}	14.8×10^{-6}	15.2×10^{-6}
Spec Ht, Btu/lb/°F	0.245	0.245	0.245	—
Elec Res (68 F), microhm-cm	7.0	6.5	6.6	6.6
MECHANICAL PROPERTIES[a]				
Mod of Elast in Tension, psi	6.5×10^6	6.5×10^6	6.5×10^6	6.5×10^6
Ten Str, 1000 psi	23	30	40	38
Yld Str, 1000 psi	15[b]	14[b]	25[c]	23.5[c]
Elong (in 2 in.), %	3	7	6	12
Hardness (Brinell)	50	57	70	75
Impact Str (Izod), ft-lb	1.5	2	1.5	3
Fatigue Str, 1000 psi[d]	8.3	10.5	11.8	12.3
Compr Yld Str (0.2% set), 1000 psi	10-15	10-14	25	24.5
Creep Str (stress for 0.5% ext in 1000 hr), 1000 psi				
400 F	8.4-10.1	8.7-11.5	—	—
500 F	—	7.4-9.8	—	—
600 F	1.4- 2.1	3.9-6.4	—	—
THERMAL TREATMENT				
Aging Temp, F	350 (16 hr)	600 (16 hr)	625 (2 hr) + 355 (16 hr)	360 (12 hr)
FABRICATING PROPERTIES				
Casting Temp Range, F	1380-1525	—	—	—
Machinability	All of these alloys have excellent machining properties			
Weldability	Can be welded by inert-gas shielded arc methods			
CORROSION RESISTANCE	Good resistance to the atmosphere; attacked by salt water			
USES	Pressure-tight castings; aircraft engine parts, expansion chambers, other parts for service at 300-500 F	Jet engine parts for service to 660 F	Structural castings for service to 400 F; engine parts, airframe parts	Structural castings for service to 300 F; engine parts, gear casings

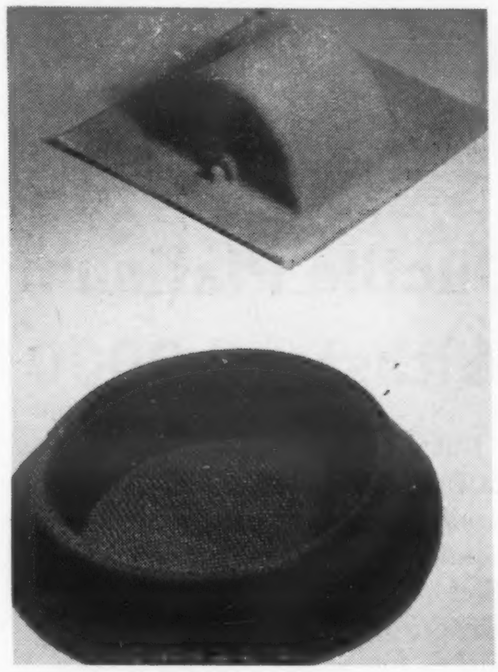
[a]Mechanical properties given for sand castings. [b]0.2% set. [c]0.1% set. [d]50×10^6 reversals in Wohler type test.

Prepared with the assistance of Dow Chemical Co. and Magnesium Electron, Inc.

◄ For more information, circle No. 363



***Fabric seat cover** (left), embossed and premolded to size, speeds up assembly of kitchen stools. Shaped fabrics can also be used to cover plastics foams (right) for a number of industrial applications.*



***Typical shapes** heat-formed from Dynel acrylic fabric include flange cover (top) and deep drawn cup (bottom).*

Heat-Shaped Acrylic Fabrics Protect Furniture, Valves

■ Design innovations in radios, furniture and many industrial products can now be achieved by using special heat-shaped fabrics of Dynel acrylic fiber, according to the Textile Fibers Dept. of Union Carbide Chemicals Co., Div. of Union Carbide Corp., 30 E. 42nd St., New York 17.

The development, said to open up a number of new uses for textile fabrics, uses the thermal pliability of acrylic fibers to achieve molded, embossed and stiffened shapes by a simple heating, shaping and cooling process. The developer says the same procedures used for molding plastics sheets are readily adaptable to the shaping of Dynel acrylic fabrics.

Among typical heat-shaped items that can be made with acrylic fabrics are: protective packages for instruments, covers for radios and outdoor furniture, industrial flange and valve covers, ribbed battery separators and many decorative products.

How forming is done

Forming is done by forcing a cold die into a stretched piece of 100% Dynel fabric and heating the die to 320 F until the fabric takes its shape; the shaped fabric is then cooled and trimmed. The producer says the shaped acrylic fabric retains its form until reheated to 320 F. A heat-shaped acrylic fabric retained its shape and size after continuous exposure to heat from a 150-w light bulb for 600 hr.

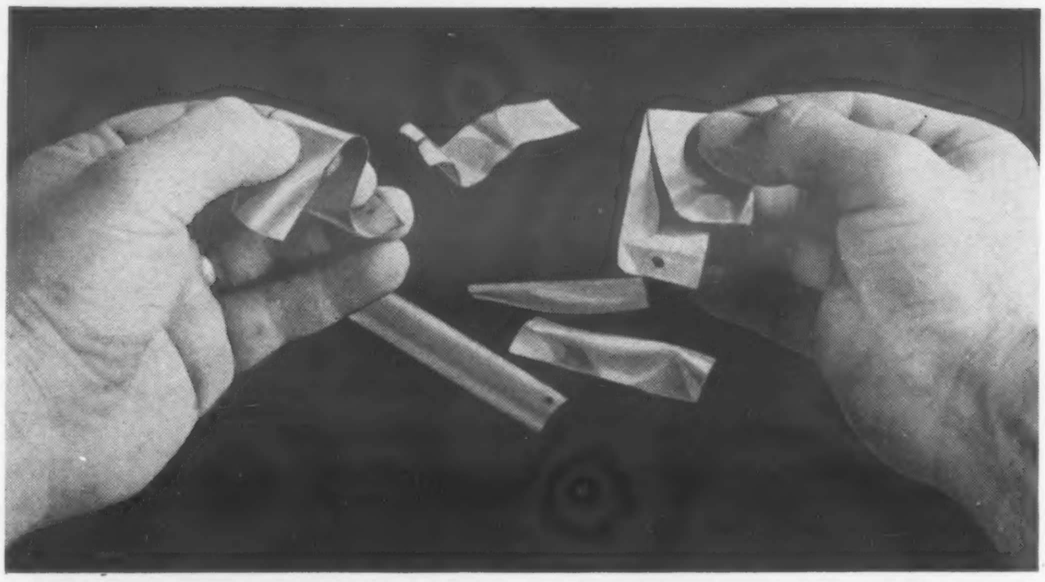
Vacuum molding with short time, high temperature infrared heating may also be used. Woven and knitted fabrics of the acrylic fiber, or blends with other fibers, may be shaped by a hot air process with molds of wood, glass, metal, plaster of paris and papier-mache.

How much formability?

According to Carbide, the extent of formability depends upon the number, size and twist of yarns in the fabric. Many woven acrylic fabrics can be drawn to 160% of their original length in a single operation, whereas woven fabric blends, such as 75 acrylic-25% cotton, can be drawn to 120% of their original length in a single forming operation.

The stiffness of a heat-shaped acrylic fabric is dependent on time, temperature and tension used during the forming operation; the higher the temperature, the stiffer the cooled fabric. Low temperature and low tension produce molded acrylic fabrics as soft as before shaping.

◄ For more information, circle No. 390



***Ductility** of a new platinum electroplate is demonstrated by bending plated strips around fingers.*

Ductile Platinum Electroplates Withstand 2000 F Indefinitely

■ Ductile, nonporous, low-cost platinum electroplates are now possible with a new plating bath chemical called Platinex III/LS, developed and marketed by Sel-Rex Corp., Precious Metals Div., Nutley 10, N. J.

Ductile, oxidation resistant

The resulting platinum electroplate is said to have better corrosion resistance at high temperatures than rhodium electroplates; tests show it withstands temperatures of 2000 F indefinitely, with no evidence of oxidation taking place. The electroplate is said to have such good ductility that electroplated sheets can be formed and crimped without cracking.

The platinum electroplate is expected to find use as a heat resistant coating for circuits and connectors in missiles and rockets, and as a coating for silicon and germanium transistors.

The producer says the plating bath chemical produces a platinum electroplate directly from the bath in one continuous operation. In conventional platinum plating, parts must be removed from the bath at frequent intervals for burnishing and scratch brushing to produce a commercially acceptable electroplate. The producer says, " . . . elimination of this costly repetitive operation with the use of Platinex makes platinum plating economical for a wide variety of industrial products."

The bath operates at 165-185 F and requires only the addition of a replenisher and water for maintenance. The lower operating temperature makes the bath long-lived and eliminates noxious fumes encountered in present platinum plating operations. The bath is said to produce electroplates in any practical thickness.

Good thermal shock resistance offered by . . .

Three Ceramic Products with High Strength

■ Corning Glass Works, Corning, N. Y. has introduced three new ceramic products having excellent thermal shock resistance. One is a family of lithium-aluminum-silicate low expansion ceramics; the others are Pyroceram cement and Pyroceram tubing. Pyroceram is the trade name for a group of materials that are essentially crystallized glasses (see M/DE, July '57, p 142).

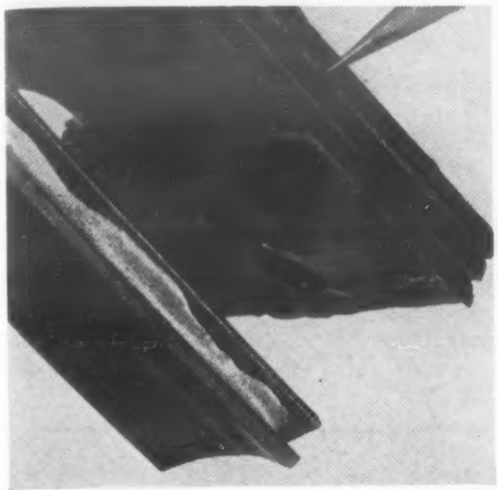
In addition to good thermal shock resistance, all three ceramic products have high mechanical strength, light weight, good dielectric properties and good resistance to chemical attack. Both the Pyroceram cement and the Pyroceram tubing are available in production lot quantities. The ceramic cement presently sells for $10 per lb.

Pyroceram cement

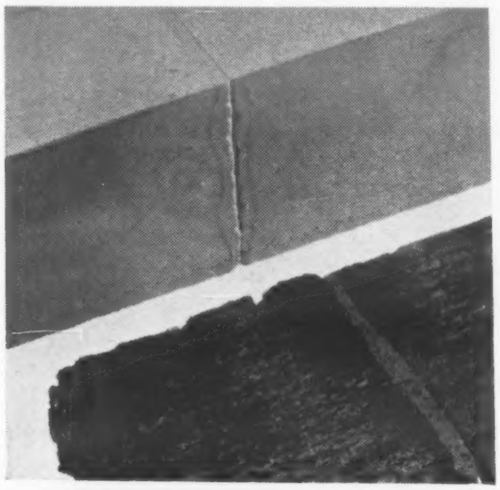
The ceramic cement, a finely powdered glass of special composition, can be used to bond most glasses to themselves, to ceramics and to stainless steels; it can also be used to bond metals to metals and ceramics to ceramics. The producer says the cement fills the need for a low temperature sealing material that can withstand service temperatures up to 800 F.

One typical application for the cement is sealing the face panel to the funnel of glass color TV tubes. Pyroceram-sealed tubes are said

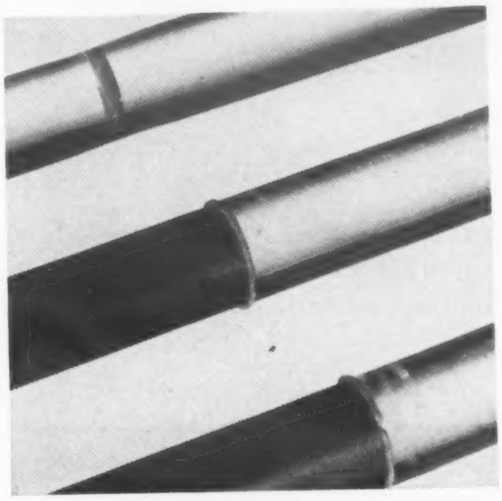
Some typical uses of Pyroceram cement



Metal-to-metal seal *of SAE 1010 steel to SAE 1010 (top), and type 430 stainless to type 430 (bottom).*



Ceramic-to-ceramic seal *of Pyroceram to Pyroceram (top), and martinsite to martinsite (bottom).*



Glass-to-glass seal *of Pyrex to Pyrex (top), and Pyrex to metal (center and bottom).*

to limit leakage of helium into a closed vacuum chamber (held at less than 2 x 10^{-5} mm Hg) to less than 0.01 $\mu\mu$liter per sec. The sealed tube is also said to withstand a high voltage breakdown test of 51 kv for 1 min.

Other uses for the cement include glass-to-metal seals for multiple leads, metal laminations and instrument windows. Typical glass-to-glass seals include double glazed window glass, hermetically sealed oven windows and electron tubes. The cement seals materials in the thermal expansion range of 90 to 110 x 10^{-7} per °F.

Pyroceram cement, when held in suspension by a low viscosity vehicle, may be applied to a sealing area by dipping or pressure flow. The uncured seal is glassy after evaporation of the vehicle and develops a partially crystalline structure after firing, resulting in a devitrified glass seal much stronger and harder than the original glass. The cement fires at 750 to 840 F.

Since the ceramic cement has a high percentage of lead oxide, special precautions should be taken while mixing and using the material. The company recommends that a respirator be worn while handling the powdered glass.

Pyroceram tubing

The ceramic tubing, available in sizes ranging from 1/8 to 3/4 in. in dia, is particularly recommended for use in heat exchangers. P. T. Clark, vice president and general manager of the Technical Products Div., says, "Pyroceram tubing in heat exchangers will permit higher rates of heat flow per unit area, allow higher operating pressures, and considerably lessen any chance of damage to the unit by abrasive particles."

The tubing is pure white and opaque, and is said to have thermal shock resistance similar to that of fused silica.

Low expansion ceramics

Manufactured for high temperature uses where material expansion is critical, Corning's lithium-aluminum-silicate low expansion ceramics are formed in a variety of shapes by slip casting, hydraulic pressing and extruding. Flexural strengths of the ceramics range from 2000 to 20,000 psi; porosities range from gas-tight to 35% porosity.

One ceramic, known as E-313, has a zero coefficient of expansion and can be used continuously at temperatures up to 1830 F and intermittently up to 2100 F. This

PROPERTIES OF PYROCERAM CEMENT

Young's Modulus, psi	6.66 x 10^6
Shear Modulus, psi	2.62 x 10^6
Poisson's Ratio	0.27
Modulus of Rupture, psi	
77 F	6000
800 F	1500
Volume Resistivity, ohm-cm	
275 F	8.550
660 F	7.030
Dissipation Factor (100 cps)	
77 F	0.0058
345 F	0.085
Dielectric Constant (100 cps)	
77 F	21.2
345 F	22.7

PROPERTIES OF PYROCERAM TUBING

Flexural Strength, psi	20,000
Vickers Hardness (diamond pyramid)	550
Water Absorption, %	0.0
Porosity	Gas-tight
Specific Gravity	2.5
Max Operating Temperature, F	1830

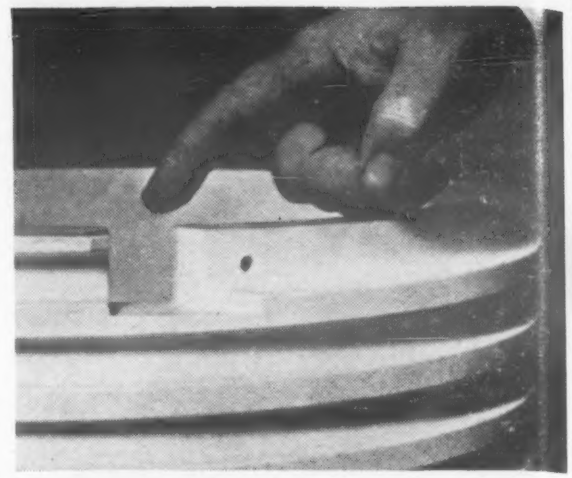
PROPERTIES OF LOW EXPANSION CERAMICS

Type ➜	E-105	E-313
Density, lb/cu ft	116	137
Specific Gravity	1.85	2.30
Total Porosity, %	20	0-5
Modulus of Rupture, psi	2000	8000
Rec Svc Temp, F	2000	1830
Coef of Ther Exp, per °F	5.5 x 10^{-7}	0
Ther Cond, Btu/hr/sq ft/°F/in.	25	25
Permeability	—	Gastight

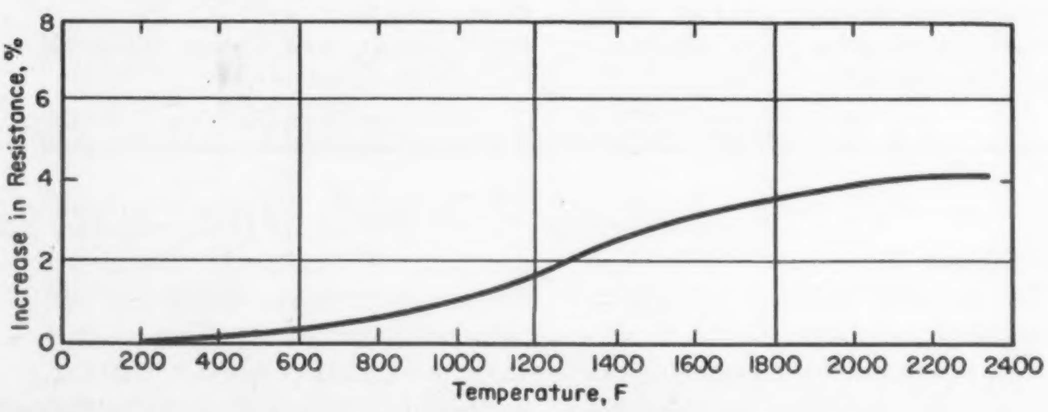
material has a flexural of 8000 psi and is gastight.

Another ceramic, designated E-105, has a coefficient of expansion of 5.5×10^{-7} per °F, a flexural strength of 2000 psi and a total porosity of 20%; it is designed for use at 2000 F.

The materials are particularly resistant to molten aluminum and are being investigated for use as linings for aluminum melting furnaces and molten aluminum containers. Other potential uses include crucibles, calcining trays and furnace supports.



***Grooved cylinder** shown above is made from Corning's low expansion ceramic.*



***Effect of temperature** on resistance of Alloy 875.*

PHYSICAL PROPERTIES OF ALLOY 875

Melting Point, F	2770
Resistivity (68 F)	
Wire, ohms/cir mil ft	875
Ribbon, ohms/sq mil ft	687
Strip, ohms/sq mil ft	687
Ther Cond (68 F), Btu/hr/sq ft/°F/ft	10.9
Density, lb/cu in.	0.256
Coef of Exp, per °F	
68-1472 F	7.7
68-1652 F	8.7
68-1832 F	9.7
68-2012 F	11.9
Max Cont Svc Temp, F	2350

COMPOSITION OF ALLOY 875, %

Chromium	22.5
Aluminum	5.5
Silicon	0.5
Carbon	0.1
Iron	Bal

Electrical Resistance Alloy with Improved Properties

■ The latest in a relatively new series of highly oxidation resistant, iron-chromium-aluminum electrical resistance alloys is said to offer improved physical and mechanical properties (as compared to foreign alloys previously available) and to be completely free of all critical materials.

According to Hoskins Mfg. Co., the new development is important because many of the iron-chromium-aluminum alloys now available 1) are limited to relatively few applications because of their low hot strength, short service life and poor working characteristics, and 2) are based on some critical materials. Hoskins' new Alloy 875 is said to have overcome these limitations.

According to Hoskins, the new alloy has excellent resistance to oxidation at high temperatures, high electrical resistivity, low specific gravity, improved uniformity and ductility, and less susceptibility to growth and distortion. It increases in resistance at high temperatures (see graph).

The new alloy was developed primarily for use in heating elements in industrial furnaces, kilns and other types of heating equipment which require continuous operating temperatures up to 2350 F.

(more What's New on p 130)

MORE WHAT'S NEW IN MATERIALS

For more information, circle No. 462 ➤

DESIGN ENGINEERING DATA*

A New, LOWER COST – High Efficiency Fluorocarbon

RULON®

- newest, *most versatile* "SUPER TEFLON".
- *Lowest priced* of all comparable fluorocarbons.
- a modified TEFLON fluorocarbon enhanced by a superior blend of additives and reinforcing agents.
- an *accepted, tested* and *proven* TEFLON offspring with broader, more efficient and more economical applications.
- a dynamic Design and Engineering material: super performance with *improved* properties.

TESTED RULON PROPERTIES:

(as compared to TEFLON†)

SUPERIOR:

Wear Resistance
Hardness
Stiffness
Cold Flow
Deformation Under Load
Compressive Strength
Thermal Conductivity

SIMILAR:

Elongation
Impact Strength
Tensile Strength
Electrical Insulation

SAME:

Low Coefficient of Friction
Extreme Heat Resistance
Chemical Corrosion Resistance
Non-flammability
Outdoor Durability
Zero Water Absorption
Flexural Strength
Non-stick Properties

†DuPont's TFE Fluorocarbon Resin

(Write for actual values)

PROVEN RULON APPLICATIONS

ELECTRICAL

Relays, Potentiometers, Antennae, Terminals and Connectors, Bushings and Washers.

CHEMICAL

Bearings for Acids and Dyes; Non-toxic Bearings for Food and Liquid Processing; Oil-free Bearings; Freon-resistant Seals; Refrigeration Seals.

MECHANICAL

Piston Rings, Torque Control Bushings, Textile Bearings, Rotary Seals, Cam Followers, Pump Bearings, Cups and Seals, Thrust Washers, Gaskets and Packings, Valve Seats.

(Write for actual applications)

RULON® a "super-TEFLON" whose properties and lower cost create applications never before possible for a designed-in and engineered material. *RULON* is the answer to a low-cost replacement for sintered metals, ball bearings, wood, glass, ceramics and expensive fluorocarbons. Select RULON *for more and longer performance at a lower cost.*

Write for further information and prices.

***plastics division: Dixon Corporation**

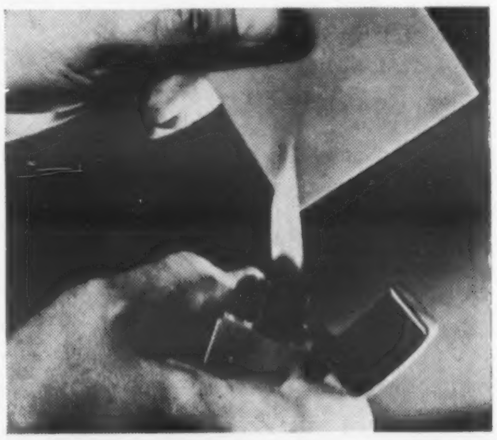
What's new IN MATERIALS

Paper-Base Laminate Is Flame Retardant

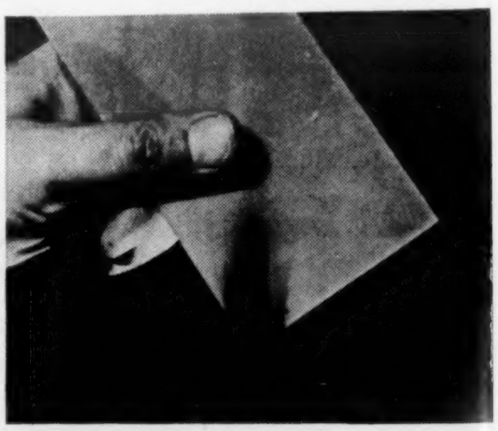
A new paper-base phenolic laminate, developed by Richardson Co., 2765 Lake St., Melrose Park, Ill., is said to combine good electrical properties with good flame retardance and good arc resistance. Additional features of the laminate are low water absorption, and low edge and center expansion.

The laminate, known as Insurok Grade XT-901, is particularly recommended for high voltage applications, terminal boards, jack spacers, relays and sliding contacts.

According to Richardson engineers, "Electrical characteristics of XT-901 exceed published NEMA values for XXXP phenolic laminates."



Flame's on: *Paper-base phenolic laminate is subjected to flame from a cigarette lighter.*



Flame's off: *Only slightly charred, laminate is unaffected by flame from the lighter.*

(more What's New on p 132)

brazed successfully with

SILVALOY

LOW TEMPERATURE SILVER BRAZING ALLOY

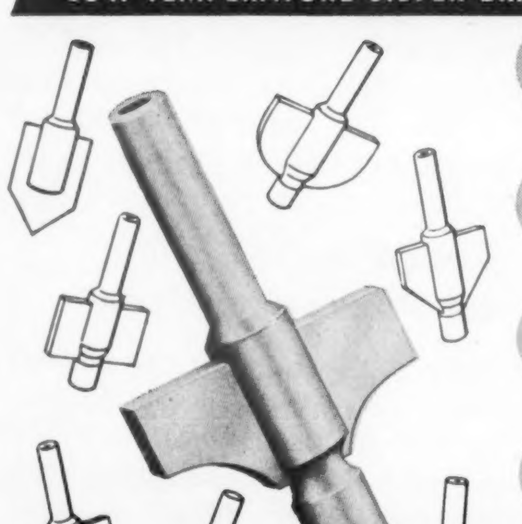
Millers Falls Router Bits and Dyno-Mite high-speed power bits are revolutionary in concept, design and materials. They both perform with such unmatched efficiency that they have reached the "top-of-the-list" in their field.

Dependable, prolonged service is a "must" for all Millers Falls products and the component parts of both bits are therefore brazed with Silvaloy. The joints are as strong as the high-speed steels they join. Millers Falls uses Silvaloy 45 and Deoxo flux for these operations.

Silvaloy Brazing Alloys and APW Fluxes are helping to speed production, lower costs and improve brazing results in many fields. Call your nearest Silvaloy Distributor for information or technical assistance. ★

The Millers Falls Company is a leading manufacturer of quality hand and power tools for home and industry for over 90 years.

MILLERS FALLS TOOLS
SINCE 1868



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Two complete reference manuals for low-temperature silver brazing and fluxing are available upon request. Send for either one or both. ★ ★ ★ ★ ★ ★ ★ ★

For more information, turn to Reader Service card, circle No. 465

What's new IN MATERIALS

Iron-Base Alloy Is Strong at 1300 F

A precipitation hardening iron-base alloy, J-1300, has been added to General Electric's list of commercially available vacuum melted alloys. GE's Metallurgical Products Dept., 11177 Eight Mile Road, Detroit 32, says the alloy is especially effective at temperatures of 1300 to 1350 F.

The alloy's rupture strength at 1300 F is comparable to or better than other iron-base alloys at 1200 F, and its minimum guaranteed tensile strength at 1200 F is 135,000 psi. Relaxation tests indicate the alloy maintains high residual strength after long exposure to stress and high temperatures.

GE's J-1300 is particularly applicable for jet engine turbine wheels, rings, shafts, compressor wheels and blades. The alloy is also suitable as a fastener material. The material is supplied in forgings and bar stock.

Four Plastics Films for Packaging Uses

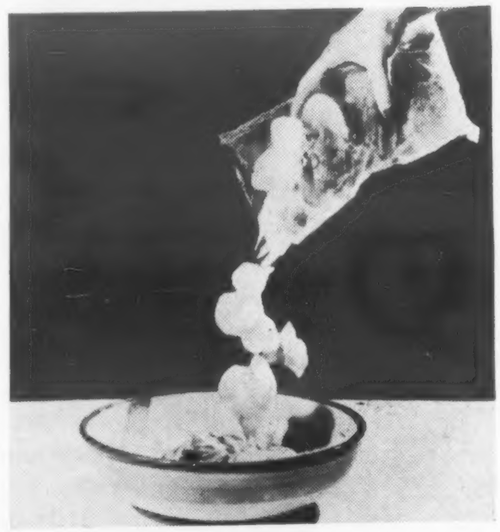
Four new and improved plastics films have been developed for packaging applications—two are cellophane and two are high density polyethylene films.

1. Polyethylene films

Two companies, W. R. Grace & Co., Polymer Chemicals Div., 3 Hanover Square, New York 4, and Phillips Chemical Co., Bartlesville, Okla., have recently introduced high density polyethylene film.

Grace's film, called Grex, is said to have excellent resistance to moisture vapor transmission—about four times better than conventional polyethylene film. Almost as transparent as cellophane, Grex high density polyethylene film is said to greatly increase the shelf life of many food products.

Phillips' high density polyethy-



Food packaging *will probably be the greatest single use for Grace's high density polyethylene film.*

lene film, called Marlex 50, is said to have good resistance to moisture, greases and gases over a wide temperature range. Like Grex, it is transparent and is said to maintain its clarity even when extruded to less than a thousandth of an inch in thickness.

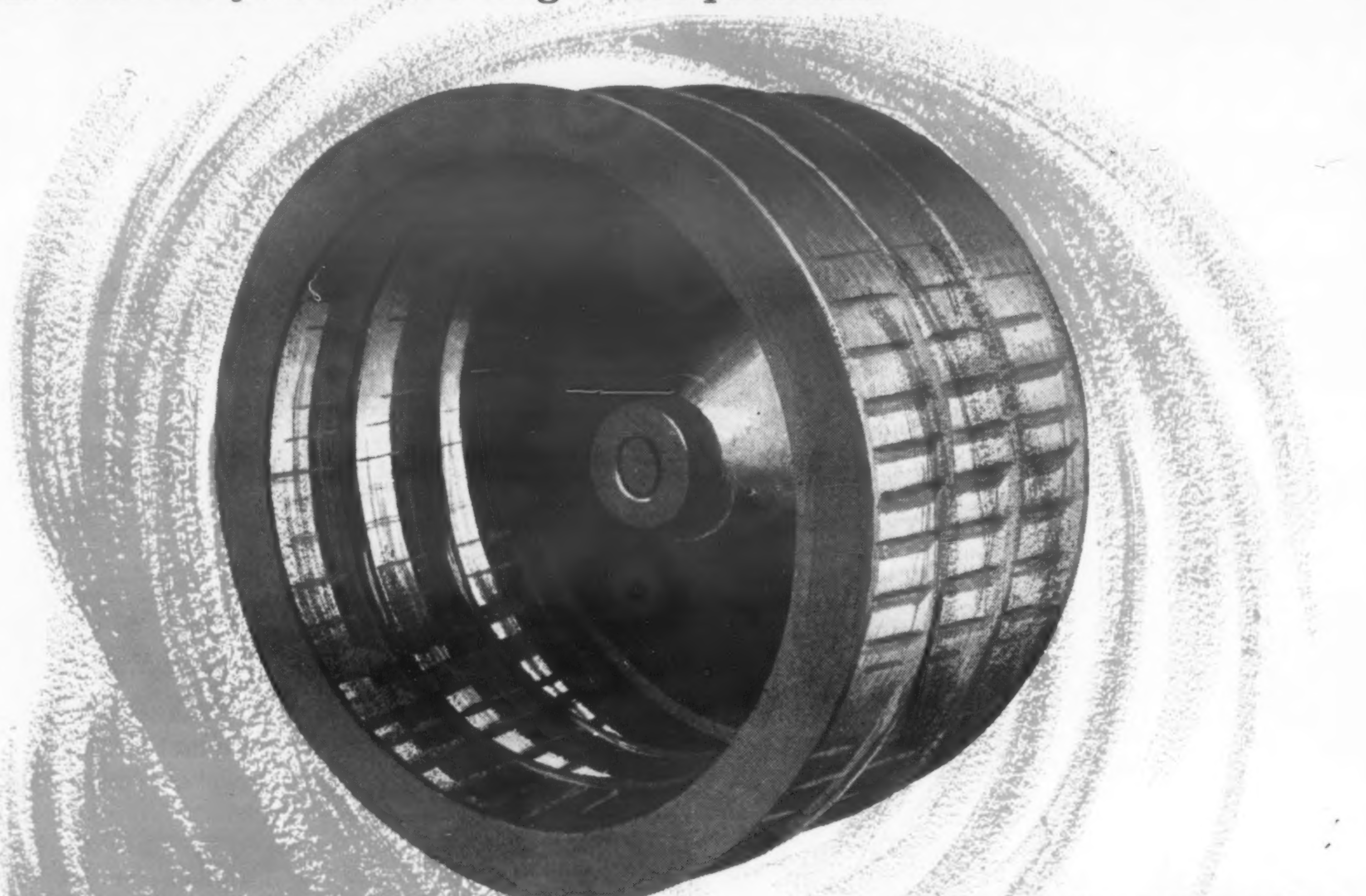
2. Cellophane films

The two improved cellophane films have been introduced by E. I. du Pont de Nemours & Co. for food packaging. One, called 300 K-202, is designed primarily as a bag film. It is a 300-gage film with a yield strength of 19,500 psi. The other film, called K-201, is designed primarily for baked goods. It has a yield strength of 21,000 psi. Both films sell for 79¢ per lb or 0.0405¢ per 1000 sq in.

Heat Resistant Alloys for Jet, Turbine Engines

Higher heat resistant parts for jet and gas turbine engines may come out of the development of two new high temperature alloys by Allegheny Ludlum Steel Corp., Henry W. Oliver Bldg., Pittsburgh 22, Pa. Both alloys, produced in billets, bars, sheet, wire and forgings, are currently avail-

HAYNES Alloys solve the *tough* heat problems



10 YEARS' SERVICE at 1600 to 1800 deg. F.

Fans with impellers or rotors made of MULTIMET alloy circulate the atmosphere inside heat-treating furnaces and are exposed to temperatures from 1600 to 1800 deg. F. They withstand both reducing and oxidizing conditions produced during cyaniding, annealing, and nitriding operations. Their average life is about 10 years.

MULTIMET is one of 12 HAYNES alloys specifically designed for use where strength at high temperatures is essential. For details on properties, forms, and prices send for descriptive literature or contact our nearest sales office. HAYNES STELLITE COMPANY, Division of Union Carbide Corporation, General Offices and Works, Kokomo, Indiana. Sales Offices in Chicago, Cleveland, Detroit, Houston, Los Angeles, New York, San Francisco.

Designed to operate at 1800 deg. F., this impeller has 180 blades formed from MULTIMET alloy sheet. Impellers range from 12 to 48 inches in diameter. Furnace rotors, cast of MULTIMET alloy, operate at temperatures up to 2100 deg. F.

HAYNES ALLOYS

HAYNES STELLITE COMPANY

Division of Union Carbide Corporation

Kokomo, Indiana

UNION CARBIDE

For more information, turn to Reader Service card, circle No. 398

What's new IN MATERIALS

CHEMICAL COMPOSITION, %

Type ➜	D-979	AF-71
Carbon	0.07	0.30
Manganese	0.25	18.37
Silicon	0.46	0.24
Chromium	14.31	12.60
Aluminum	1.06	—
Nickel	43.58	—
Tungsten	3.86	—
Molybdenum	3.82	3.02
Titanium	2.94	—
Boron	0.01	0.18
Nitrogen	—	0.19
Vanadium	—	0.80
Iron	29.63	64.30

able in limited quantities.

D-979, a nickel-chromium-base material produced by the consumable electrode vacuum melting process, is designed for jet and gas turbine applications requiring high strength at temperatures up to 1600 F. The producer says the alloy has excellent tensile and creep rupture properties at this temperature.

AF-71, an iron-chromium-manganese-base material, is a comparatively inexpensive alloy with outstanding creep rupture properties at temperatures of 1000 to 1500 F. The low strategic alloy is said to be almost as strong at 1500 F as alloys containing 40 to 50% cobalt.

Vinyl Fluoride Film Is Weather Resistant

A new plastics film with superior outdoor weathering characteristics is now under development at E. I. du Pont de Nemours & Co., Inc., Wilmington, Del. Carrying the experimental designation, Type R, the new film is being produced only on a laboratory scale and samples are in extremely limited supply.

Type R film is based on a new polymer, not now commercially available, the predominant monomer of which is vinyl fluoride. Du Pont says the film is clear and colorless and has good transpar-

PRODUCT-DESIGN

MEMOS FROM DUREZ

Heavy-duty parts
Making epoxies flame-resistant | **Metallized phenolics**

Chrysler Corporation

Rugged

Got a job that's "too tough for phenolics"?

You might never think of phenolic for a part like this Chrysler-engineered automotive oil-pump gear—subject to wear, heat, friction, constant oil immersion.

But you'd be reckoning without the ruggedness of a new phenolic, *Durez 16771.*

Parts molded from this glass-fiber-filled compound have a flexural strength of 20,000 psi, compressive strength of 16,500 psi. Their tensile strength is 7,000 psi. Modulus of elasticity in tension is 3.0×10^6 psi. What's more, the heat distortion point of these parts is up around 600° F.

Payoff • These properties, plus excellent resistance to oil, water, and acid, made Durez 16771 appear to have some of the properties needed for the Chrysler oil-pump gear. After extensive experimenting and testing, Chrysler engineers developed the plastic gear to replace the usual metal part.

Results: *new gears of Durez 16771 outwear metal gears nearly 3 to 1—show no performance-affecting wear after 200,000 miles; save about two-thirds of the cost of metal gears; run more quietly.*

For a data sheet describing this high-strength phenolic, check opposite "16771" on the coupon.

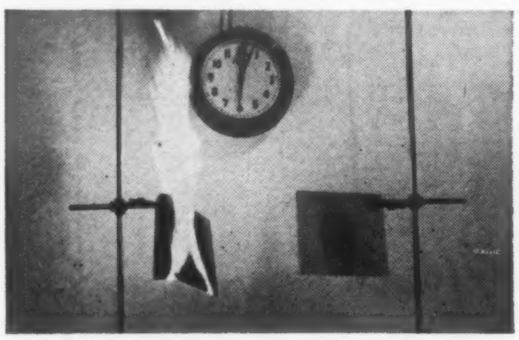
How to make epoxies resist flame

Your epoxy laminates and castings will shrug off heat, moisture—even fire—if you cure them with a new Durez product called HET® Anhydride.

In the picture that follows, the laminate cured with a conventional hardener ignites in less than 30 seconds and burns to destruction in about 3 minutes. Exposed to a similar flame source for the same time, a HET-cured laminate snuffs itself out as soon as the flame source is removed.

This leads to some interesting possibilities. For instance, you can now make glass-reinforced laminates that keep practically all their flexural strength, *even when heated within the 300-350° F range.*

You can make potting resins that retain room-temperature electrical properties at high humidities *and at temperatures above 300° F*—and won't feed a fire.

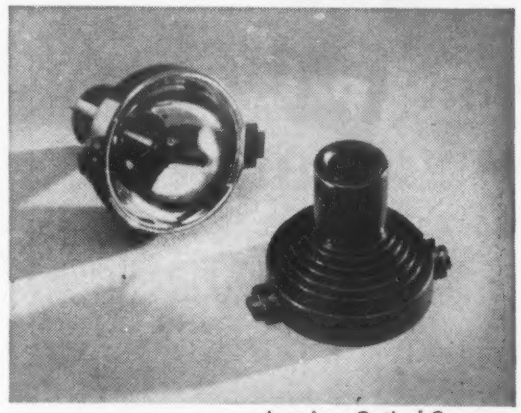


For easier casting or wet layup, you need not handle HET Anhydride hot. You can mix it with another anhydride to form a curing system that *stays liquid at room temperature.* Toxicity is very low.

If you'd like complete information on HET Anhydride, methods of use, and properties of cured resins, check the coupon for Bulletins 19 and 43.

Bright Idea

Next time you want to put a bright reflective surface on a part, think of *metallized phenolic.* It may save you a costly production step.



American Optical Company

For instance, this housing for a microscope lamp requires a mirror to focus the light.

To sidestep the cost of a custom-made mirror, the housing is molded of Durez phenolic. Then an aluminum mirror is deposited right on the plastic by vacuum evaporation.

This is easy to do with the Durez compound chosen for this part. It provides a good hard surface for metallizing. It incorporates other wanted properties: high impact strength and low thermal conductivity.

You're on sure ground when you base bright ideas like this on phenolics. They give you a bigger choice of controlled properties than any other material in their class. You can select the right balance from *more than 150 Durez compounds.*

To take a fresh look at today's phenolics, just check the coupon for a new four-page bulletin describing some typical Durez molding compounds and what you can do with them.

For more information on Durez materials mentioned above, check here:

- ☐ High-impact Durez 16771
- ☐ HET Anhydride—Bulletins 19 and 43
- ☐ Phenolic molding compounds—descriptive bulletin

Clip and mail to us with your name, title, company address. *(When requesting samples, please use business letterhead.)*

DUREZ® HOOKER CHEMICALS PLASTICS

PLASTICS DIVISION

HOOKER ELECTROCHEMICAL COMPANY

1407 Walck Road. North Tonawanda, N. Y.

For more information, turn to Reader Service card, circle No. 385

What's new IN MATERIALS

ency. It is said to have high mechanical strength and excellent resistance to chemicals. It also transmits ultraviolet light and retains its properties over a wide temperature range. An early laboratory sample has not discolored or become brittle after 10 years exposure to the elements in Florida.

Type R film appears to have promise as a surfacing material for metals, wood and composition boards because of its ability to resist mechanical damage and prolonged weathering.

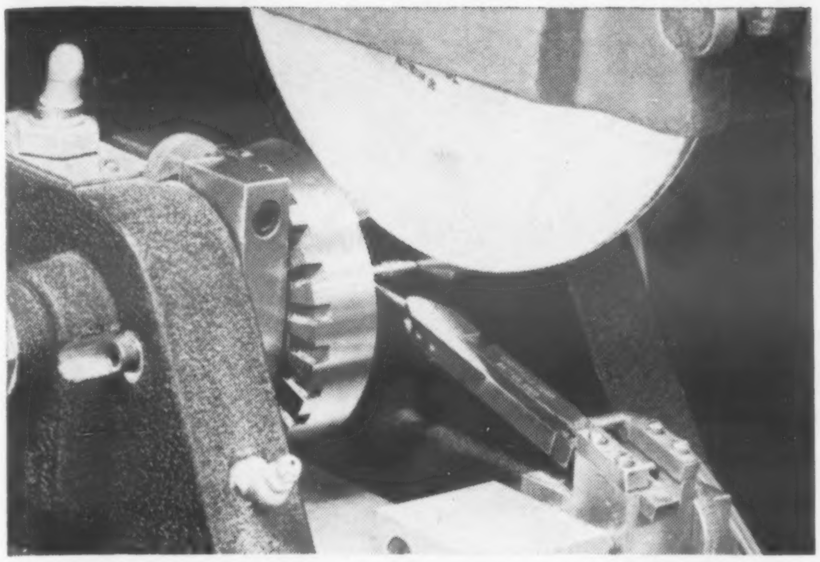
Cork Gaskets Have Good Oil Resistance

A new cork gasketing material, designed to eliminate seepage and leakage of liquids and gases in applications where neither cork composition nor cork and rubber have been completely satisfactory, has been developed by Armstrong Cork Co., Lancaster, Pa. According to the producer, the cork gasketing material, called Uniphase, has greater resistance to contained fluids than other resilient gasket materials because the binder more closely approaches the chemical inertness of cork itself.

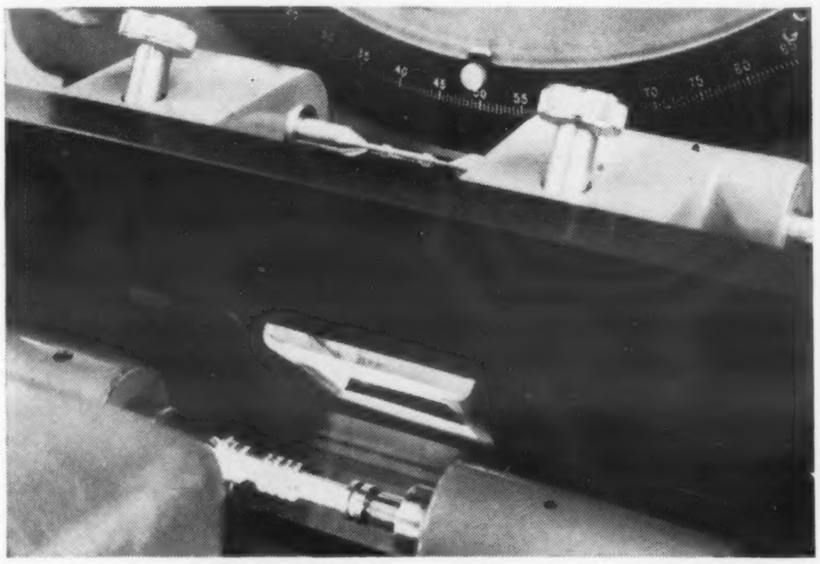
The accompanying photographs of an oil penetration test were taken through a glass and show how Armstrong's Uniphase cork compares with cork composition and cork-rubber gasket materials in resisting fluids under heat and pressure.

Uniphase cork is said to seal at flange pressures as low as 100

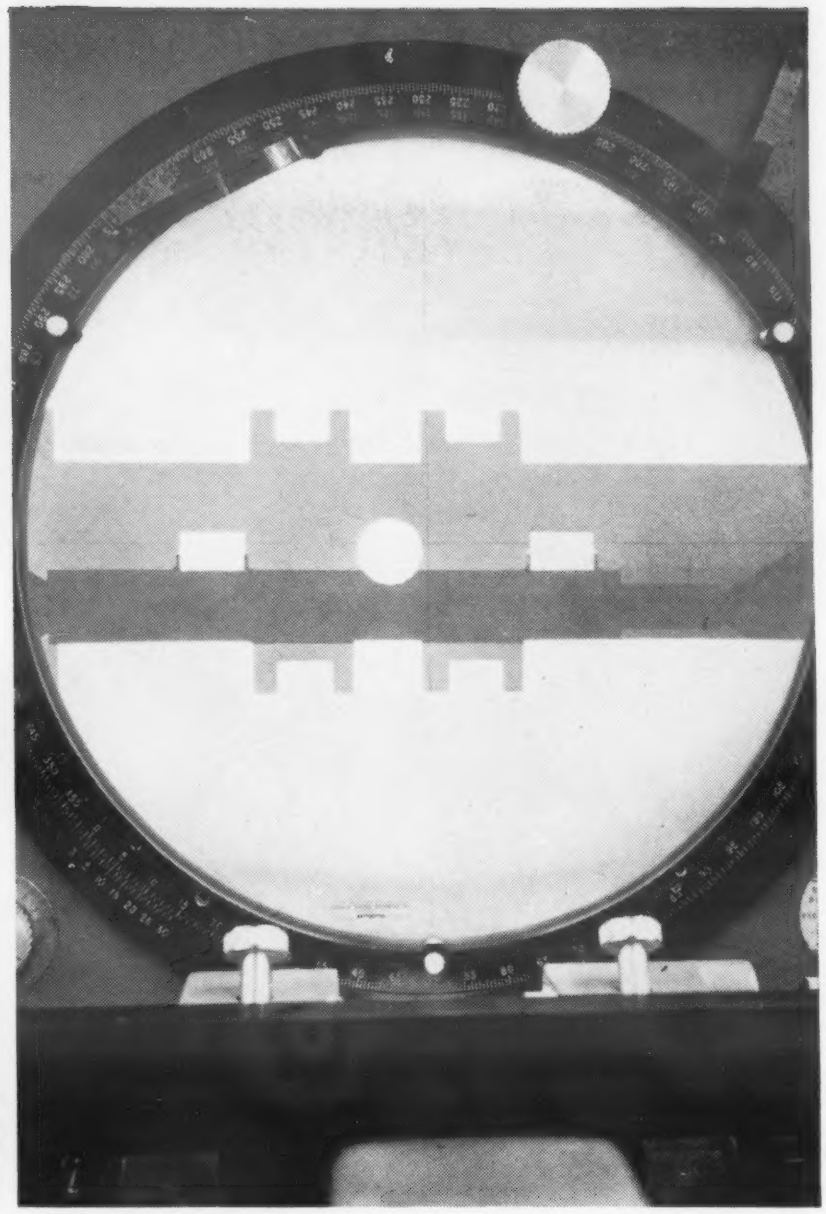
PROPERTIES of most engineering materials can be found in M/DE's *Materials Selector* reference issue, published last September. Names and addresses of suppliers are also listed.



1. Piston lands on hydraulic control valves are trimmed on a surface grinder fitted with motorized centers.



2. After trimming, piston and sleeve are mounted on worktable of Kodak Contour Projector for simultaneous projection by two light sources to gage amount of stock removal.



3. Overlap of piston and sleeve images is indicated by black area; overlap can be measured quickly by traverse of one part and observation of dial indicator.

How to do a 7½-hour gaging job in half an hour

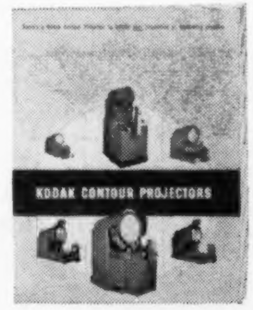
How would you solve a gaging problem like this one?

In developing hydraulic control valves, engineers at a major firm producing aircraft components worked out a neat method of trimming piston lands in relation to ports in their mating sleeves.

But meeting the required .0002″ overlap between piston lands and sleeve ports meant using several different gages to determine the amount of stock which had to be trimmed. Result: *7½ hours to trim each valve.*

To solve the problem, quality control engineers now use a Kodak Contour Projector with two light sources and two filters, one red and one green. This system projects a superimposed image of the piston on the sleeve. Where an overlap occurs, the red and green images combine into a black image. The width of this black overlap gives the amount of trim required. Result: *just ½ hour needed—7 hours saved on each valve!*

Maybe you've come up against a gaging problem that's eating up time and money in large quantities. To learn how you can solve it by optical gaging, send for the booklet "Kodak Contour Projectors." Write to:



Apparatus and Optical Division
EASTMAN KODAK COMPANY, Rochester 4, N. Y.

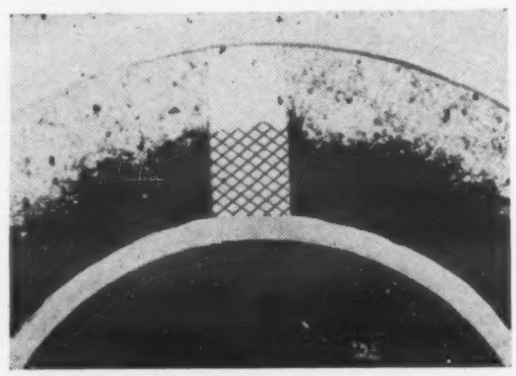
the KODAK CONTOUR PROJECTOR

Kodak
TRADEMARK

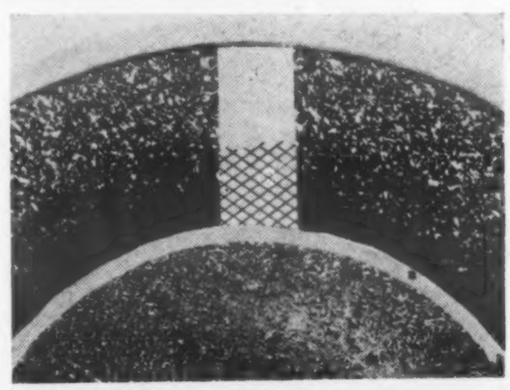
For more information, turn to Reader Service card, circle No. 373

psi and as high as 4000 psi; it seals at very low flange pressures because the elastomeric binder actually conforms to the flange surface. Uniphase is said to retain a high degree of the natural conformability of cellular cork.

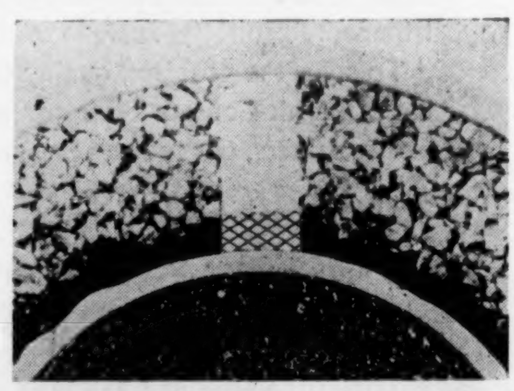
Oil Resistance of Gasketing Materials



Cork composition: *Oil has penetrated more than halfway across gasket.*



Cork-rubber: *Oil has penetrated about one-third of the way across gasket.*



Uniphase cork: *Oil penetration is blocked at inside perimeter of gasket.*

(more What's New on p 142)

For more information, turn to Reader Service card, circle No. 453

For more information, turn to Reader Service card, circle No. 476

For more information, turn to Reader Service card, circle No. 375

What's new IN MATERIALS

Three New Adhesives for Bonding Plastics

Three new adhesives are now available for bonding plastics foams, nylon and plastics laminates to themselves and to other materials.

1. Adhesive for foams

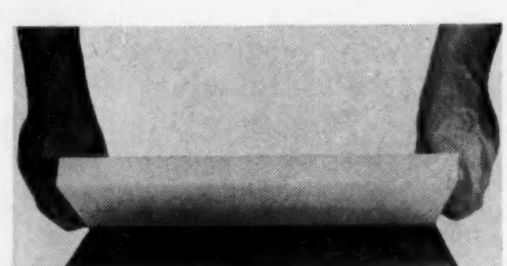
A new adhesive described as a high strength, quick grab, fast drying, trowelable mastic for bonding styrene and urethane foams to themselves and to other materials has been introduced by Rubber & Asbestos Corp., 225 Belleville Ave., Bloomfield, N. J. Recommended especially for bonding rigid foamed styrene cores to wood and metal panels in sandwich constructions, Bondmaster G458 is reported to have good resistance to humidity and freezing temperatures.

2. Adhesive for nylon

Nylosil 820 is the name for a new pressure sensitive adhesive that requires no priming, welding or heat curing to join nylon to itself or to other materials. Developed by Ions Exchange and Chemical Corp., 44 Leonard St., New York 13, the adhesive is said to be resistant to water and hydrocarbons. It sets at room temperatures and is available in a wide range of viscosities.

3. Adhesive for laminates

A fast setting, solvent-type synthetic rubber adhesive has been developed by Pierce & Stevens Chemical Corp., 710 Ohio St., Buffalo 3, N. Y. for joining plastics laminates to themselves and



***Foamed styrene** is bonded to air conditioner drip pan with Rubber & Asbestos Corp.'s new adhesive.*

A Different Light on the Subject...

Include Price in the Many Advantages Solid Brass Has Over Other Materials

Many concerns are discovering that the availability of solid brass—at competitive prices—makes it extremely advantageous to use in place of other materials.

For example, parts of the desk lamp shown here made by J. Schrader Co., Cleveland, Ohio, are now being made of Bridgeport F-37 Ultra Fine Grain Brass Strip. Formerly, these same parts were made from a plated product. Now, with solid brass as an active cost competitor, its inherent qualities of workability, beauty and durability over other metals and methods are employed with excellent results.

This is an opportunity that warrants your attention. Your Bridgeport salesman will be glad to show you how solid brass can benefit your product. You'll find that he will work with you in every way. Look into the benefits of solid brass . . . *including its cost.*

matched Bridgeport Brass Alloys *to your job*

BRIDGEPORT BRASS

Offices in Principal Cities • Conveniently Located Warehouses

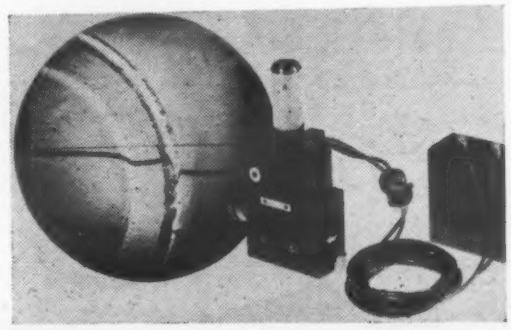
Bridgeport Brass Company, Bridgeport 2, Connecticut
In Canada: Noranda Copper and Brass Ltd., Montreal

For more information, turn to Reader Service card, circle No. 389

to wood, steel, aluminum, fiberboard, leather and fabrics. Called Hybond, the adhesive is said to produce an odorless, nonstaining bond that has good heat and water resistance, high strength, and sufficient elasticity to resist shock and fatigue. Hybond is available in two types: Type 80 for roller, brush and trowel application; and Type 56 for spray application.

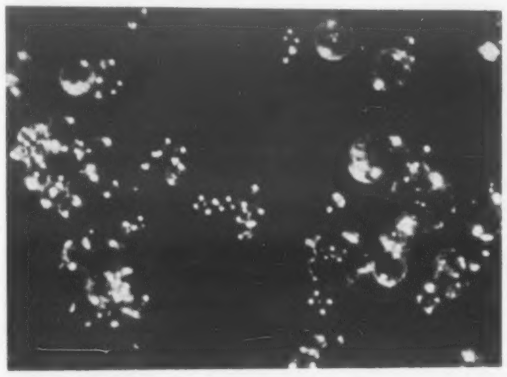
Dielectric Material Is Stable at 1500 F

A low density, heat resistant dielectric material, called Eccospheres, is now available from Emerson & Cuming, Inc., 869 Washington St., Canton, Mass. at a price just below $5 per lb in quantity. The product, described as thin-walled, hollow glass microspheres which resemble fine white



Measuring depth of scratches—Accurate measurement of scratches and pitted areas on the surfaces of metallic sheet and tube is now possible by using the optical instrument shown above. Developed by Boeing Airplane Co., Seattle, Wash., the instrument, standing 7 in. high, has a set of lenses with 36X magnification, and works on the principle used by astronomers for measuring the depth of moon craters. A light source strikes the bottom of the scratch or pit at a known angle and the length of the shadow is measured automatically by the instrument. Boeing's optical instrument gives depth measurements to one ten-thousandth of an inch.

What's new IN MATERIALS



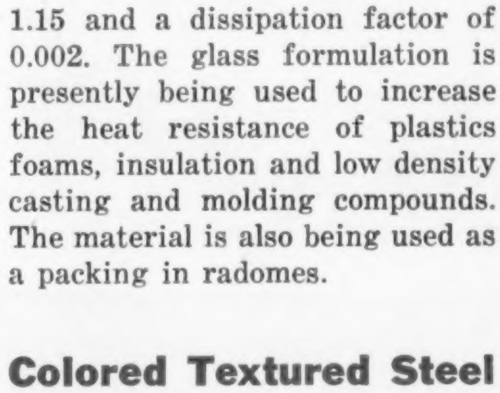
Basic structure *of Emerson & Cuming's low density dielectric material is shown in this photomicrograph.*

sand in bulk, is stable at temperatures up to 1500 F.

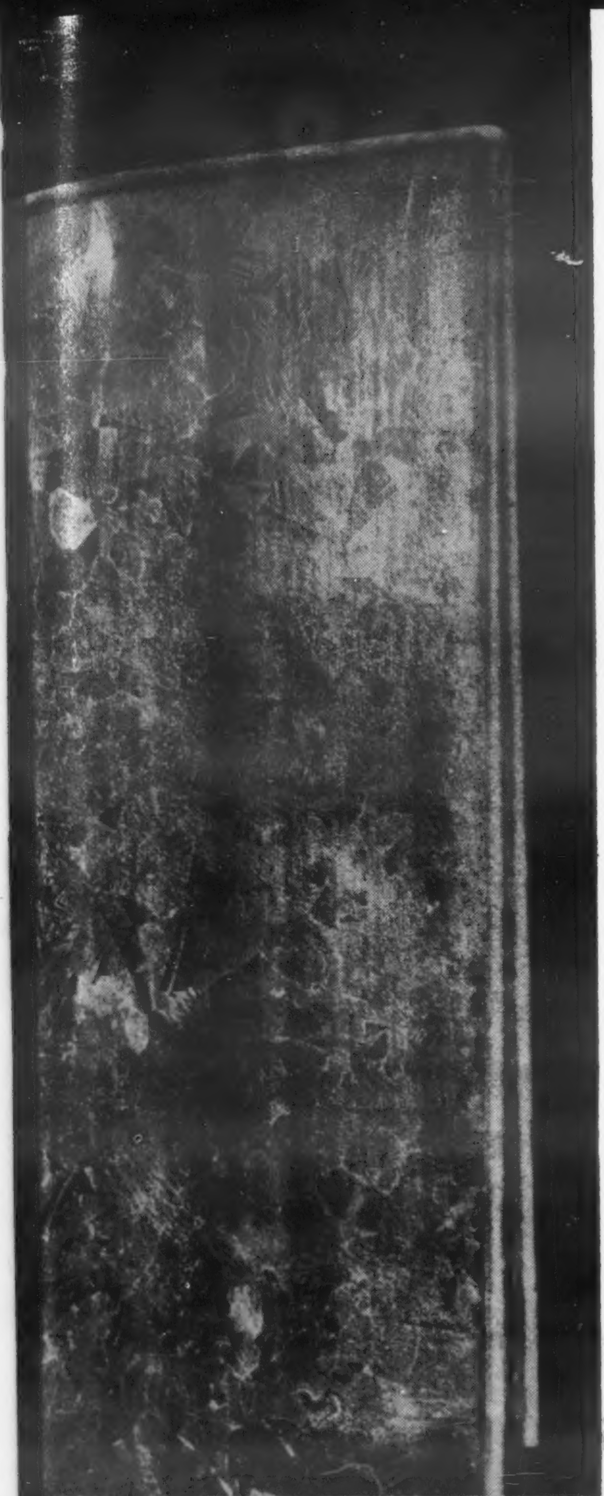
It has a dielectric constant of 1.15 and a dissipation factor of 0.002. The glass formulation is presently being used to increase the heat resistance of plastics foams, insulation and low density casting and molding compounds. The material is also being used as a packing in radomes.

Colored Textured Steel

Sharon Steel Corp., Sharon, Pa., has announced the availability of Sharonart, a rolled-in patterned steel strip, in a wide range of colors including gold and bronze. The colored coating is applied by vacuum metallizing. The producer says, " . . . vacuum metallizing imparts a brilliant, translucent metallic coating over the textured metal at less cost than by elec-



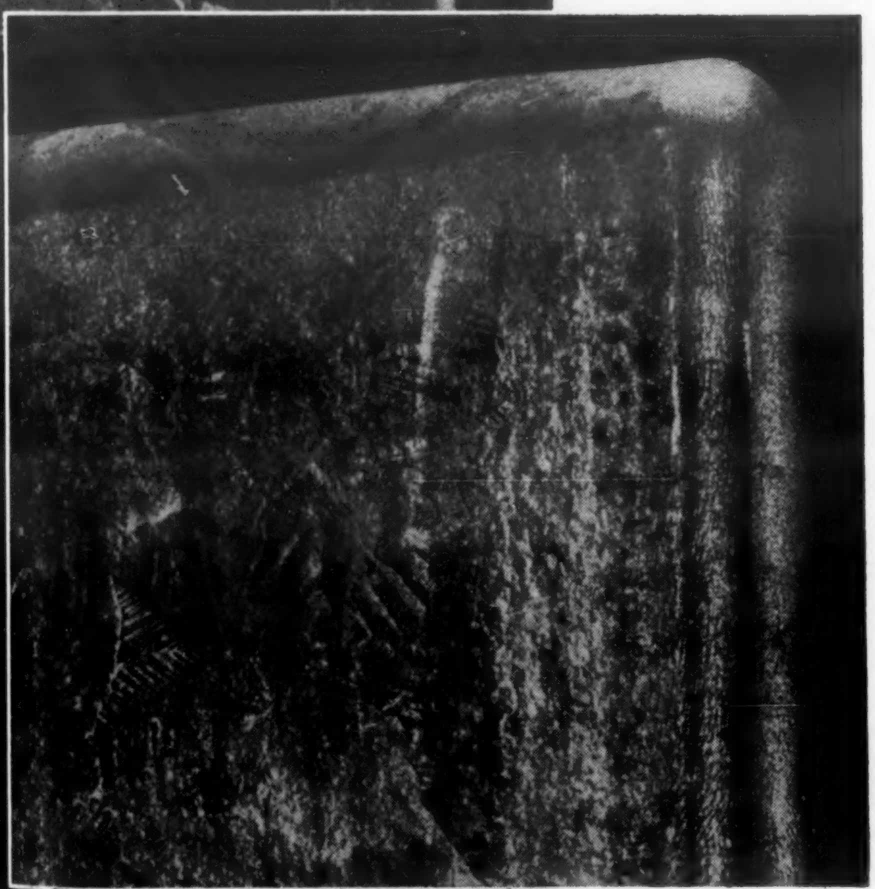
Calculator housing *is one of the many uses anticipated for Sharon Steel's new colored textured steel.*



Handkerchief fold

on USS Galvanized Steel Sheets

proves the zinc stays on



These are unretouched pictures of twice-folded USS Galvanized Steel Sheets. The sheet in the smaller picture is magnified three times actual size.

We cut a piece from a sheet of USS Galvanized Steel—bent it double—
then we bent it double again.

But look at the zinc coating along the outside of the bend. Not one bit of the coating flaked off! What's more, we restraightened the sheet and still not one speck of zinc came loose!

This kind of adherence means you can fabricate USS Galvanized Steel Sheets in ways you may not have thought possible.

Unless otherwise ordered, USS Galvanized Sheets are chemically treated to inhibit the formation of white oxide—sometimes called humid storage stain.

United States Steel Corporation – Pittsburgh
Columbia-Geneva Steel – San Francisco
Tennessee Coal & Iron – Fairfield, Alabama
American Steel & Wire – Cleveland
United States Steel Supply – Steel Service Centers
United States Steel Export Company

United States Steel

USS

TRADEMARK

troplating. In addition, any color can be applied to textured steel by vacuum metallizing."

The coating, though not impervious to severe abrasion, is said to resist scratching and is resistant to salt spray tests in excess of 100 hr.

Anticipated uses for the colored textured steel include automotive trim, office furniture, business machine housings, appliance covers, casket handles, electric wall switches, door panels, bread boxes, mail boxes, metal baskets, ash trays, legs for tables and chairs, and door panels.

Sharonart is produced in 20 standard patterns including abstractions, pebbled surfaces, geometric patterns and simulations of fabrics, leathers and wood grains.

Other News . . .

Ferrous metals

▶ Stabilization of austenitic stainless steels is accomplished at North American Aviation, Inc. with a low temperature chilling machine made by Cincinnati Sub-Zero Products Co., 3930 Reading Rd., Cincinnati 29, Ohio. The unit is said to achieve complete transformation of steel from Austenite to martensite without warpage.

▶ Silver clad stainless steel is now being marketed by American Silver Co., 36-07 Prince St., Flushing 54, N. Y. The producer says the clad steel makes a durable electrical contact material.

Nonferrous metals

▶ A phosphor bronze strip called 200-Plus has been developed by Miller Co., Rolling Mill Div., 99 Centre St., Meriden, Conn. The new product is said to have greatly increased ductility, while retaining the strength and hardness of regular spring tempered bronze.

▶ Seamless aluminum tubing in diameters from ¼ to ⅝ in. o.d., in wall thicknesses from 0.010 to 0.002 in., and in lengths up to 5 ft is now available from H & H Machine Co., Inc., Norristown, Pa. The tubing is

made of high purity aluminum (99.8% with 0.015% max iron content).

▶ High purity aluminum is now commercially available from Kaiser Aluminum & Chemical Sales, Inc., 919 N. Michigan Ave., Chicago 11, in ingot form. Aluminum ingot of 99.99% purity may be obtained in 6, 15, 30 and 50 lb sizes.

Nonmetallics

▶ The new plastic polypropylene is being extruded into sheets at Seiberling Rubber Co., Newcomerstown, Ohio. The sheets, available in sizes up to ¼ in. thick in 48 in. widths, are sold under the trade name of Seilon PRO.

▶ A high density gasket material called Accopac AN-890 has been developed by Armstrong Cork Co., Lancaster, Pa. for sealing Freon refrigerants. It is available in rolls, sheets, ribbons and die cut pieces.

Finishes

▶ A new version of a phosphate coating chemical called Bonderite is said to operate at very much lower temperatures than presently used phosphate coating chemicals, according to Parker Rust Proof Co., 2177 E. Milwaukee St., Detroit 11. Parker says a sheet metal processor has claimed a 70% savings in over-all heat costs by using the cold Bondrite system.

▶ A primer that contains 92% metallic zinc is said to give lasting protection to steel surfaces without the need of a top coat. Called Poly-Zinc and available from American Cold Galvanizing Co., 31 Hudson St., Cambridge 38, Mass., the coating can be sprayed or brushed on clean steel surfaces.

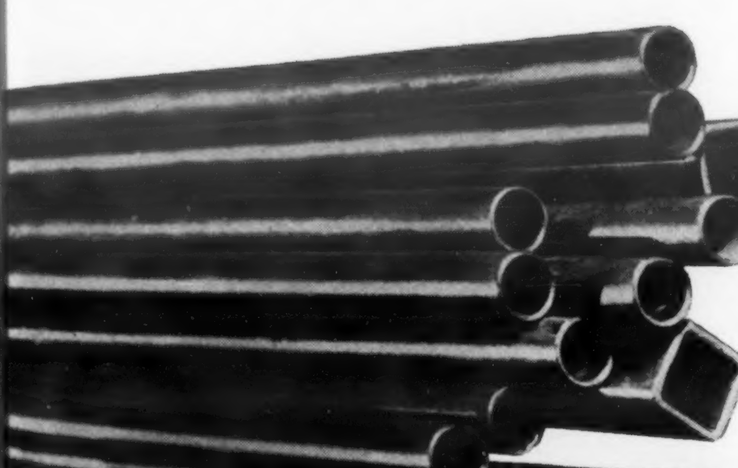
Joining materials

▶ An automatic welding process, developed and manufactured by Lincoln Electric Co., 22777 St. Clair Ave., Cleveland 17, Ohio, is said to arc weld steel at speeds ranging up to 300 in. per min. The process, called Innershield, uses a new type of flux-containing coiled wire electrode.

▶ Chemlok 607, a clear liquid adhesive, has been found to be a good adhesive for bonding the new fluorocarbon elastomer, Viton A, to steel, copper, brass, aluminum, titanium, magnesium, and chromium plated steel. The adhesive is available from Lord Mfg. Co., Special Products Div., 1635 W. 12th St., Erie, Pa.

"Whom do I call for mechanical tubing?"

"Why, your USS Shelby Distributor, of course!"



When a steel tubing problem confronts you, get in touch with your Shelby* Distributor. His ideas, experience and engineering know-how will prove most valuable.

Your Shelby Distributor carries a complete stock of USS* Shelby Seamless Mechanical Tubing—round, square, rectangular, or other special shapes in commercial sizes from 1/4" OD to 10 3/4" OD. Wall thicknesses from .035" to 2.000" in a wide range of steel grades and anneals.

So contact your USS Shelby Distributor. He is experienced, capable and close at hand. He gives speedy, efficient service. Contact him!

"Shelby Tubing is made by the world's largest and most experienced manufacturer of tubular products—National Tube."

National Tube
Division of USS United States Steel

*TRADEMARK

Columbia-Geneva Steel Division, San Francisco, Pacific Coast Distributors • United States Steel Supply Division
United States Steel Export Company, New York

For more information, turn to Reader Service card, circle No. 435

MATERIALS AT WORK

Brazing—cont'd from p 12

only a small portion of the fitting (or expanded end tubing) with an acetylene or plumber's torch. When proper temperature has been reached the soldering or brazing wire is applied at the junction and flows by capillary action to produce a positive seal. The accompanying photos show some steps in the fabrication and installation of the piping system.

Brazing *is easily accomplished because capillary flow of silver solder makes it unnecessary to apply torch and/or filler metal to the entire periphery of the joint: the silver merely flows to the blind side of the joint.*

Silver-brazed joints *are shown in this close-up.*

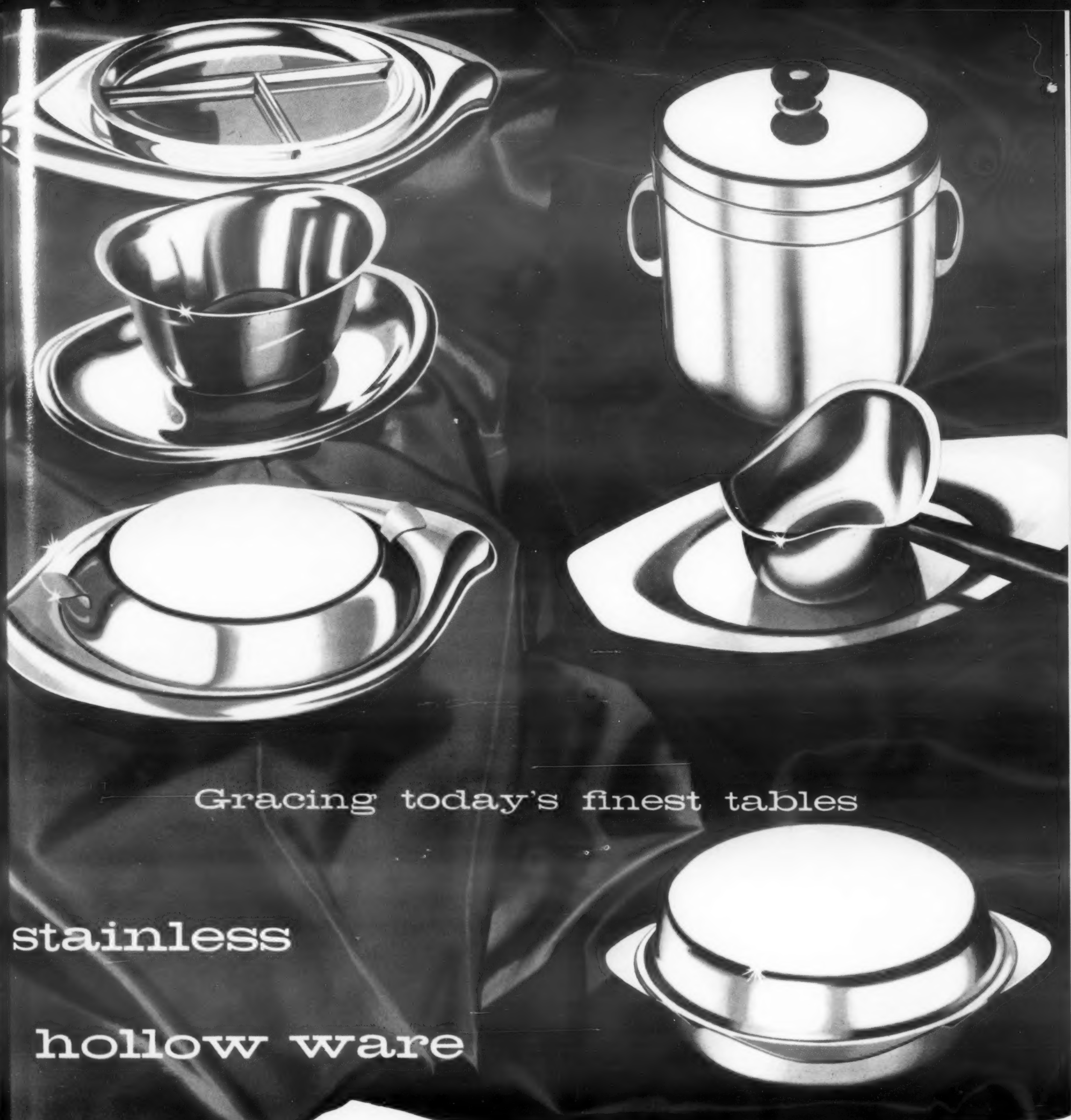
Stainless Arch for Airport Building

The arched roof of the new Arrivals Building at New York International Airport (see photo below) was made of stainless steel because it offers excellent corrosion resistance, strength, ease of fabrication and reduced maintenance.

The roof is composed of stainless steel panels framed by two

Electro Metallurgical Co., Div. of Union Carbide Corp.

Stainless panels *offer strength, corrosion resistance.*



fabricated of

Superior

STAINLESS STRIP STEELS

MARK II design
by INTERNATIONAL Silver Company
Meriden, Connecticut

STRATA design
by SHEFFIELD Silver Company
New York, New York

Stainless—without care! Modern hollow ware of Superior Stainless Steel has the sheen of precious metal without penalty of upkeep . . . strength to resist dents and scratches in service . . . and "willingness" in fabrication that permits free range in design and manufacturing methods. For full details on Superior Stainless grades, sizes and tempers fitting your applications, address our Sales Department.

Superior Steel

DIVISION OF
COPPERWELD STEEL COMPANY
CARNEGIE, PENNSYLVANIA

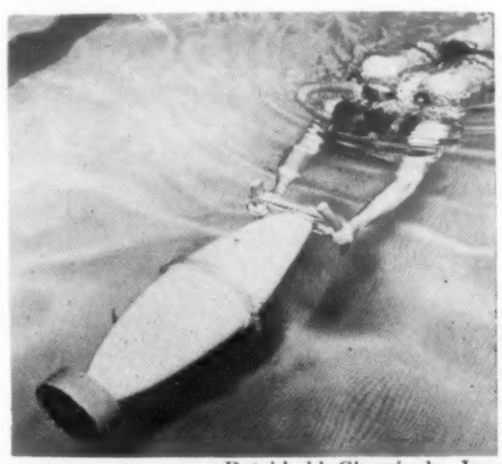
For more information, turn to Reader Service card, circle No. 426

6-ft deep plate girders which span the entire arch. Overall, the roof spans 238 ft, and the arch is 107 ft deep and 48 ft high. Ends of the roof are anchored in huge concrete blocks.

Panel 1/4 In. Thick May Replace TV Tube

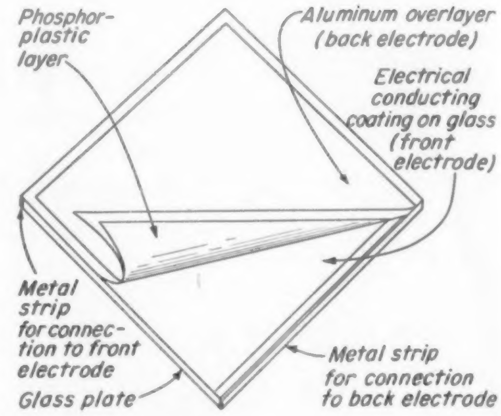
The idea of "television-on-the-wall" may soon become a reality as a result of Westinghouse Electric Corp.'s new experimental television display screen that is said to be brighter than any previous one reported, yet no thicker than a picture frame. According to Westinghouse, the new screen combines an electroluminescent panel and a flexible, built-in storage and control structure made of a ferroelectric material (barium strontium titanate).

The screen is made by laminating electroluminescent and ferro-

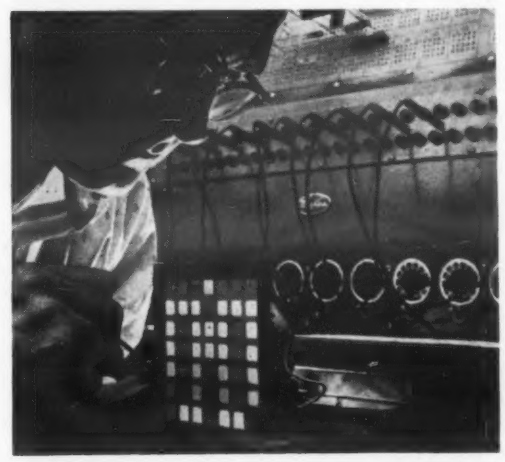


Reichhold Chemicals, Inc.

Underwater pull—Thanks to a new self-powered propulsion unit, underwater sports enthusiasts are now able to enjoy hour-long excursions at depths of up to 100 ft. The cigar shaped unit (shown above), made of glass-reinforced polyester resin, is extremely tough and durable but weighs only 1½ lb submerged. It is said to be capable of propelling a 190-lb man at about 2.2 mph. Steering handles, controls and propeller guards are made of aluminum.



Layers *making up electroluminescent panel.*



Checkerboard display screen *is experimental model of solid state television.*

electric layers which have been divided into the many separate components required to produce a detailed picture (see photo). The electroluminescent panel is composed of a thin glass plate coated with a transparent, but electrically conducting, film; a layer of phosphor-embedded plastic; and an aluminum overlay (see sketch). When electricity is applied to the two conducting layers, the phosphor in between lights up.

According to Dr. E. A. Sack, manager of dielectric materials, Westinghouse Research Laboratories, the new screen is expected to overcome three serious limita-

SOURCES of most engineering materials can be found in M/DE's *Materials Selector* reference issue, published last September. Properties of all materials are also given.

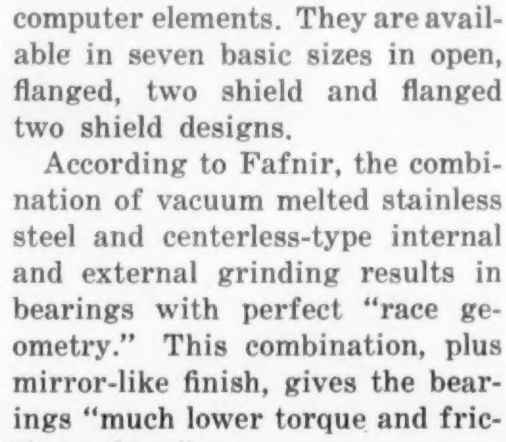
tions associated with the conventional cathode ray tube: 1) inconvenient size and shape, 2) limited maximum brightness, and 3) susceptibility to flicker. It overcomes the problem of flicker by providing for continuous excitation of the screen, i.e., the ferroelectric cells store and control the information to be displayed and distribute excitation to the screen without interruption.

Present experimental models are less than $\frac{1}{4}$ in. thick and have a brightness three times that of conventional television screens.

Stainless Ball Bearings Now Vacuum Melted

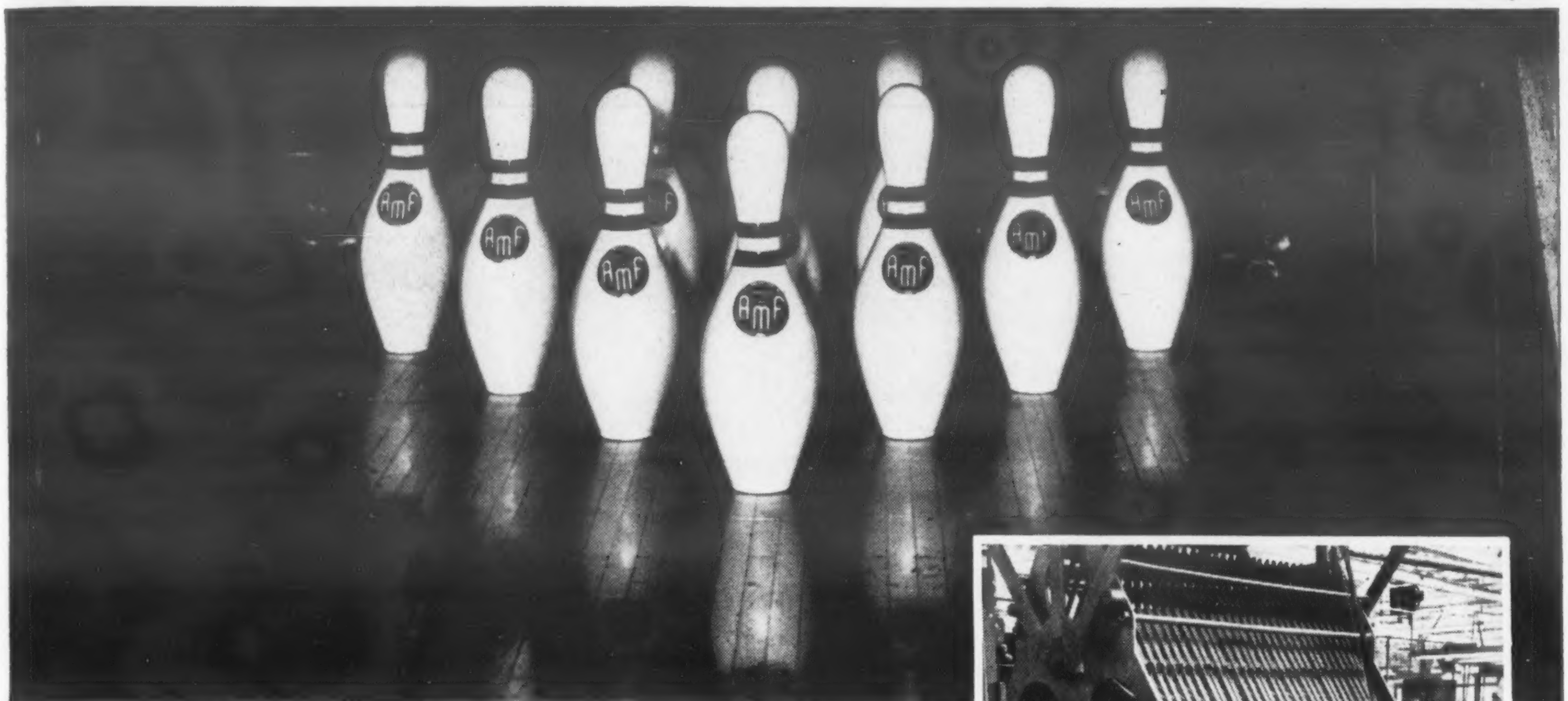
The miniature ball bearings shown in the accompanying photo are said to be the first to be made entirely of vacuum melted stainless steel. The bearings, developed by Fafnir Bearing Co., are intended for use in sensitive control instruments, missiles and computer elements. They are available in seven basic sizes in open, flanged, two shield and flanged two shield designs.

According to Fafnir, the combination of vacuum melted stainless steel and centerless-type internal and external grinding results in bearings with perfect "race geometry." This combination, plus mirror-like finish, gives the bearings "much lower torque and friction values."



Miniature ball bearings *vacuum melted of stainless steel.*

Report from AMF...Leading Manufacturer of Automatic Pinspotters:



ALMCO Barrel Finishing Solves $37,000 Problem By Improving Finish On Track Mechanism

At American Machine & Foundry's Buffalo plant, Almco barrel finishing equipment imparts a fine microinch finish to distributor tracks used in bowling's automatic pinspotter.

HERE'S HOW ALMCO BARREL FINISHING saves American Machine & Foundry Co. $37,000 a year on an intricate product — an automatic pinspotting machine!

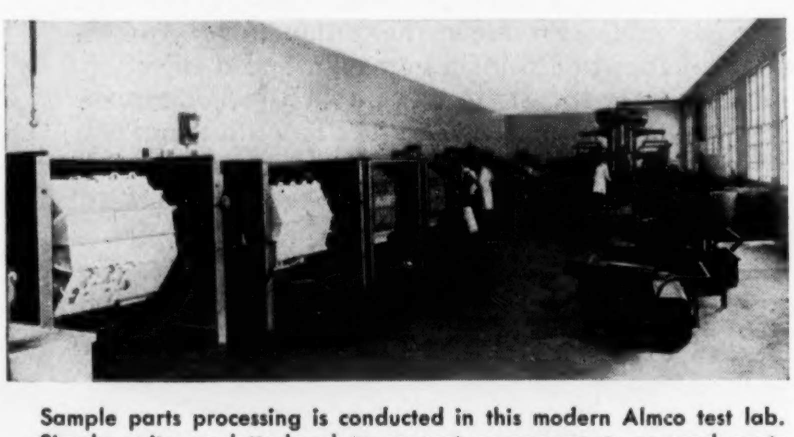
The pinspotter — a fully-automatic unit for setting bowling tenpins — had developed an isolated problem spot: A nylon gear which meshed with the teeth of the distributor track was rubbing against microscopic rough spots and surface irregularities. This caused the gear to wear at a faster-than-normal rate.

IMPROVING THE TRACK FINISH by usual methods required about 70 minutes for each track. Cooperation between AMF and Almco engineers, however, resulted in a special "fixture" to hold 29 track units in an Almco Model DBF-800-48-1 barrel finishing machine.

Tracks now attain a 32 microinch finish at a time rate of 10 minutes each. Costs were cut $37,000 annually, and the complete Almco installation actually paid for itself in less than five months!

Do you have a finishing problem on large parts? Or do you have smaller parts that must be accurately deburred and polished? In either case, find out what Almco barrel finishing can do for you.

ALMCO'S TECHNICAL STAFF will examine your product parts and provide sample processing. You'll get a detailed report with recommendations. No obligation, of course. Send in your sample parts with specification requirements. Your Almco sales engineer can make the arrangements, if you wish.



Sample parts processing is conducted in this modern Almco test lab. Simply write on letterhead to request arrangements or send parts direct to Almco at Albert Lea, Minnesota. Enclose specifications required.

Send for Free Barrel Finishing Handbook

52 pages of case history facts and descriptions of barrel finishing processes. Detailed cost charts on finishing of typical parts. Send for your free copy today.

ALMCO

QUEEN PRODUCTS, INC.

37 Marshall Street • Albert Lea, Minnesota
Subsidiary of KING-SEELEY Corporation

Sales and Engineering Offices in Chicago, Detroit, Los Angeles, Newark, New Haven and Philadelphia

IN ENGLAND: *Almco Division of Great Britain, Ltd., Bury Mead Works, Hitchins, Herts, England*

For more information, turn to Reader Service card, circle No. 399

PRICES AND SUPPLY

...AT A GLANCE

ANOTHER CUT IN COPPER PRODUCTION has been made by Phelps Dodge Corp., the nation's second largest copper producer. The latest reduction amounts to 20%, or about 3500 tons per month. This is the fifth curtailment Phelps has made since Oct '56.

PRICE OF NYLON YARN for automobile tires was recently reduced by Du Pont by about 7.7%, or 10¢ per lb. The move was interpreted as an attempt to increase use of nylon in the manufacture of tires for new cars. The price cut came right on the heels of General Motors Corp.'s decision to drop plans (for cost reasons) to equip its Chevrolet Div.'s 1959 models with nylon cord tires.

ALL GRADES OF HIGH PURITY SILICON HAVE BEEN REDUCED IN PRICE by Du Pont. The price cuts, varying from $5 to $40 per lb, were announced simultaneously with the start-up of the nation's first full-scale plant. Some of the price changes include: Semiconductor Grade No. 1, $320-355 per lb, down from $360; Semiconductor Grade No. 2, $220-245 per lb, down from $250; Semiconductor Grade No. 3, $130-155 per lb, down from $160; and Solar Cell, $90 per lb, down from $100.

PRODUCTION OF PRIMARY ALUMINUM is slated for a 180,000-ton-per-year increase when Ormet Corp.'s new reduction plant goes into full production at the end of the year. This will make Ormet, which is jointly owned by Olin Mathieson Chemical Corp. and Revere Copper & Brass, Inc., the nation's fourth largest aluminum producer.

PRICES OF POLYPROPYLENE molding and extruding compounds have now been set at 56¢ per lb for truckload quantities of natural color and 65¢ per lb for truckload quantities of standard colors. According to Chemore Corp., U. S. and Canadian representatives for Montecatini, 19 different colors are now available.

GREATER QUANTITIES OF MOLYBDENUM AND MOLYBDENUM-BASE ALLOYS in the form of bar, billets and castings will be available as a result of Climax Molybdenum Co.'s new 80,000-lb-per-year plant scheduled to go on

stream this summer. According to Climax, initial production will be used primarily for guided missile components.

POLYVINYL ACETATE EMULSIONS WILL BE PRODUCED at an annual rate of 20 million pounds at Celanese Corp. of America's new plant in Belvidere, N. J. The material, used primarily in the manufacture of water-thinned latex paint, is now being widely used for such things as adhesives, nonwoven fabrics, textile finishing and paper coating.

DOMESTIC IRON POWDER PRODUCTION is scheduled for a 50-ton-per-year increase when Alan Wood Steel Co.'s new plant goes into production early in 1959. According to Alan Wood, the new plant will be the first to utilize ". . . a workable 'fluid bed' process for the direct reduction of iron ore." It is also one of the first major self-contained iron powder plants in the country.

PRICE OF GOLD MAY INCREASE FROM $35 per oz to $100 per oz if the Government decides the prediction that Russia is planning to back its ruble with gold is accurate. According to Merrill E. Shoup, president of Golden Cycle Corp., "Our position abroad would be quickly undermined . . . and we would be caught without gold as Russia caught our military without missiles."

PRICES OF TITANIUM MILL PRODUCTS WERE RECENTLY REDUCED by Titanium Metals Corp. of America. Overall price reduction amounts to more than 10%; some products—high strength alloy plate and billets—were lowered by as much as 20-30%. According to the company, this is the seventh price reduction since 1954 for a total reduction of about 45%.

PRODUCTION OF COLD DRAWN SEAMLESS MONEL TUBING will be doubled by International Nickel Co. at its Huntington, W. Va. Works. According to International Nickel, the move was made necessary by ". . . existing and anticipated future demands for seamless cold drawn nickel alloy tubing, especially extra long monel tubing."

A NEW STEEL BAR MILL WILL BE ERECTED by Ceco Steel Products Corp. at Lemont, Ill. According to the company, the mill will have an annual capacity of 120,000 net tons of billet-sized ingots. It is expected to be in operation by the fall of 1959 and running at capacity by 1960.

The next quarterly tabular report on Prices of Materials will appear in the September issue.

A Review of the Phosphate Coatings

Specified for the Protection of Metal Surfaces

By HUGH GEHMAN, Assistant Manager, Product Development Dept., AMCHEM PRODUCTS, INC.

Phosphate coatings are protective inorganic finishes that actually change the chemical nature of metal surfaces. The metal reacts with the applied phosphate solution to form a nonmetallic, crystalline coating which serves to:

- **Improve paint adhesion**
- **Provide protection against corrosion**
- **Increase lubricity of friction surfaces**
- **Facilitate mechanical deformation of metals**
- **Decorate—in many instances**

Satisfactory protection of steel, zinc and aluminum surfaces against corrosion, paint peeling and blistering, and hard wear requires precision methods of chemical conversion coating.

Types of Conversion Coatings

There are seven classes of chemical conversion coatings commonly specified and used throughout industry today. They are as follows:

Zinc-iron phosphate (ACP Granodine®). This is the heaviest type of coating (gray in color) used for prepaint treatments on steel, iron and zinc surfaces. The process requires five or six operations: cleaning; rinsing; rust removal, if necessary; coating; rinsing; and a second rinse. Coating weight ranges from 100 to 600 mg per sq. ft.

Medium or large volume production of automobile bodies, appliances, projectiles and cabinets can be handled effectively.

The coating solution improves paint adhesion by forming a crystalline deposit over the metal surface. This deposit is rough, as revealed microscopically, and so offers an ideal gripping surface for paint particles.

Manganese-iron phosphate (ACP Thermoil-Granodine®). This is a heavy black coating used on friction surfaces to prevent galling, scoring and seizing of parts. Typical metal parts treated are pistons, piston rings, gears, cylinder liners, camshafts, tappets and various small arms components.

Iron phosphate (ACP Duridine®). This is a comparatively new process that places a light coating on surfaces for improved paint adhesion. Since cleaning and coating occur in the same bath, it has only three to five stages.

The iron phosphate treatment is a spray process suited for medium to large volume, large or small work. Precleaning is normally unnecessary, an economy factor in its favor.

Products protected by this process are steel or iron fabricated units, such as cabinets, washing machines and refrigerators. Weight of coating is 50 to 100 mg per sq. ft.

Zinc phosphate (ACP Lithoform®). This is a crystalline coating produced on galvanized iron and other zinc surfaces—also cadmium—for improving paint adhesion. The purpose of the coating is to provide a paint-gripping surface and to prevent the reaction between acidic components of the paint and the zinc metal, with the formation of soaps and loss of paint adhesion.

This coating is applied in weights of 75 to 500 mg per sq. ft. There are no limitations on volume or production or on size of products treated. Zinc phosphate coating is used on zinc alloy die castings, zinc or cadmium plated sheet or components, hot dip galvanized stock, and Galvanneal.

Amorphous phosphate (ACP Alodine®). This is a relatively new protective coating for aluminum and aluminum alloys. It may be used in place of anodic deposition for improved paint adhesion and corrosion resistance.

This coating is practical for production in any volume. Coating weight is 100 to 600 mg per sq. ft. Products treated include helmets, belt buckles, aircraft and aircraft parts, bazookas and rocket motors, roofing and siding. Particularly good when aluminum is painted prior to forming.

Zinc-iron phosphate for oil absorption (ACP Permadine®). This is a relatively heavy coating adapted to the retention of rust-inhibiting drying or nondrying oils and waxes on ferrous metal surfaces. The coating is applied to a weight of 1000 to 4000 mg per sq. ft.

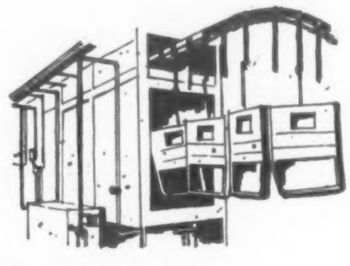
The process is satisfactory for large or small work in any volume—nuts, bolts, hardware, guns, tools, etc.

Zinc-iron phosphate for metal forming (ACP Granodraw®). This is a specialized coating used in conjunction with a suitable lubricant to facilitate the cold mechanical deformation of steel. The coating acts as an anchor for the lubricant throughout drawing, extrusion, and cold forming operations.

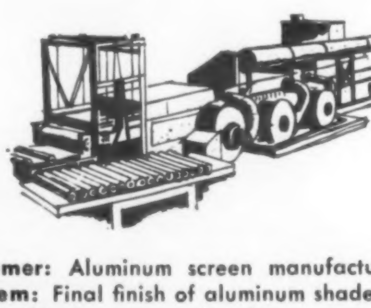
It is a successful treatment for products such as blanks and shells for cold forming, heavy stampings, impact extruded shapes, drawn wire and tube.

For more complete information about any one or all of these chemical conversion coatings, contact an ACP sales representative or write us at Ambler, Pa.

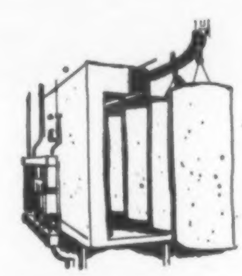
Typical Installations of Phosphate Coating Systems



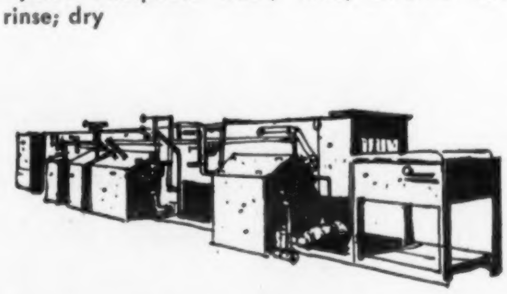
Customer: Truck manufacturer
Problem: Preparing cab parts for painting
Cycle: Phosphate wash; phosphate wash; rinse; chromic acid rinse; dry



Customer: Aluminum screen manufacturer
Problem: Final finish of aluminum shade screen
Cycle: Wash; rinse; phosphate coat; rinse; chromic acid rinse; dry



Customer: Water heater manufacturer
Problem: Preparation of water heater shells for synthetic enameling
Cycle: Phosphate wash; rinse; chromic acid rinse; dry



Customer: Hardware manufacturer
Problem: Preparing hardware parts for painting
Cycle: Wash; rinse; phosphate coat; rinse; chromic acid rinse; dry

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News OF INDUSTRY

Improvement of Materials Major Aim of New Labs

The improvement of existing materials and the development of new and better materials has always been one of the major aims of research. Within the past few years the number of new research projects and development laboratories has increased substantially. The following brief reports cover some of the most recent work being done in the field of engineering materials.

▶ Studies to determine what happens when metals dissolve in their own salts are presently under way at Stanford Research Institute, Menlo Park, Calif. One discovery—that nickel has appreciable solubility in molten nickel chloride, while iron and cobalt have little or none in their fused salts—has made possible a new method of obtaining pure nickel from stock contaminated with cobalt. According to the Institute, only a small percentage of all known metals have been investigated along these lines thus far.

"We keep a close check on this bath every step of the way."

▶ A new laboratory equipped to perform research on foamed plastics was recently built by Dayton Rubber Co. Called the Freedlander Research and Development Laboratories, the new facility augments Dayton's previous research work with adhesives and rubber foams.

▶ A research program aimed at increased understanding and use of selenium and tellurium is now under way at Battelle Memorial Institute. Principal goal of the research is to investigate and develop new uses for these elements in metals, organic chemicals, electrochemical solutions and semiconductors. The research is being sponsored by a group of selenium and tellurium producers.

▶ A major research program, sponsored by zinc and lead producing companies in the U. S., Canada, Mexico, Great Britain, South America and Australia, has been launched under the direction of the Industry Development Committees of the American Zinc Institute, Inc. and the Lead Industries Assn. Purpose of the research is the creation of ". . . appropriate new knowledge and potential new products and uses

aimed at increasing the world-wide consumption of zinc and lead."

▶ A product development laboratory has been opened by the Electro Minerals Div., Carborundum Co. According to the company, the new laboratory will provide industry with technical information on such things as aluminum oxide, boron carbide, silicon carbide, abrasive grains and powder, and many other materials.

▶ Evaluations of new or improved Du Pont products will be conducted by the company in a new $5 million product development laboratory. According to Du Pont, the laboratory will service its electrochemicals and pigments departments and is equipped to do customer research in the metals, plastics, paint, textile, paper, ink and allied chemical fields.

Titanium Symposium Scheduled By NYU

The heat treatment and alloying of titanium will be the subject of a special two-day technical meeting sponsored by the Dept. of Metallurgical Engineering, New York University.

The meeting, to be held Sept 8-9, will cover both practical and theoretical problems. Some of the papers to be delivered include: "Problems and Progress in the Heat Treatment of Titanium Alloy Sheet," "Effect of Prestrain on Age-Hardened Properties," and "Titanium-Aluminum Alloying and Alloy Behavior." A panel discussion on the "Present and Future of Titanium" has also been scheduled.

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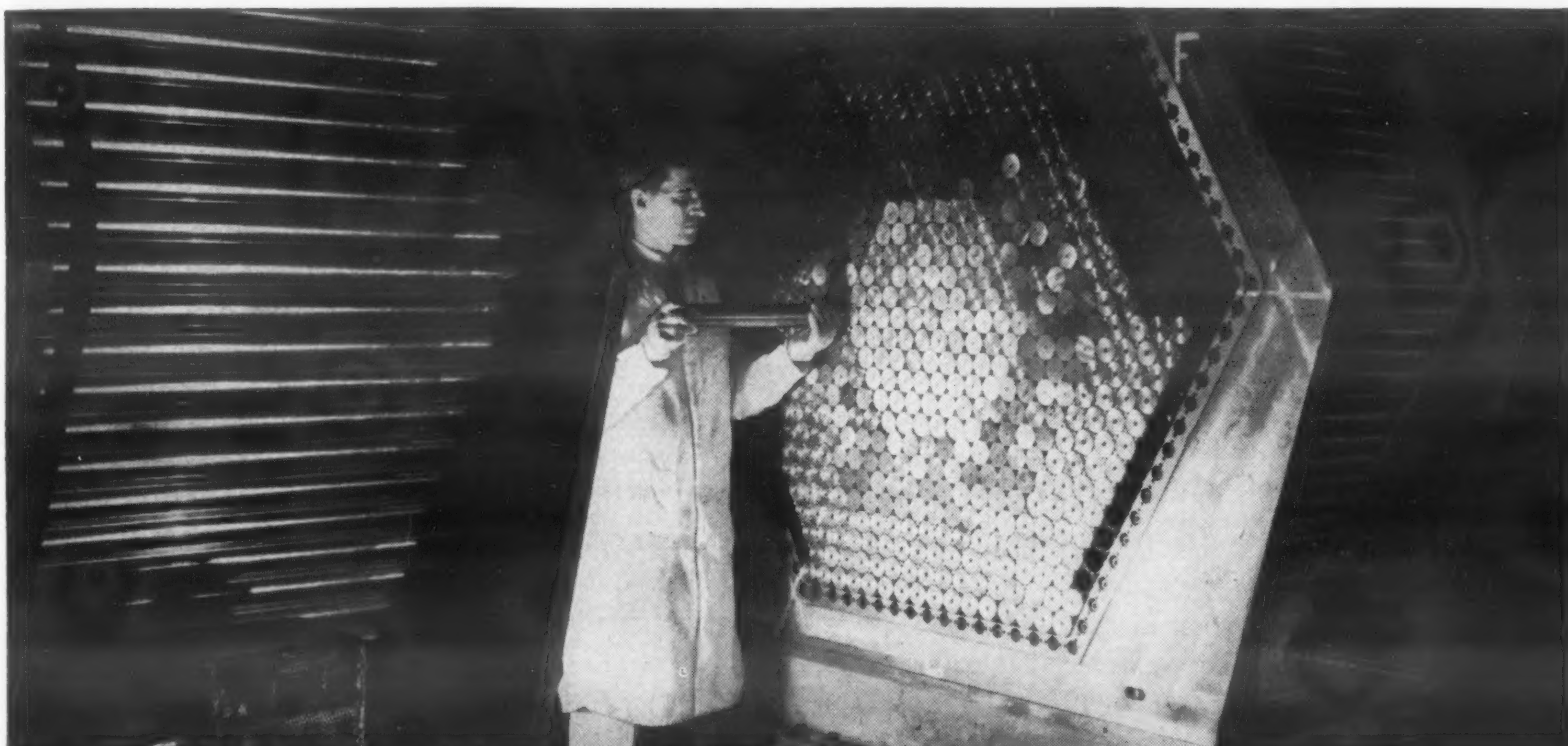

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News OF INDUSTRY

Participating in the symposium will be Titanium Metals Corp. of America; Titanium Div., Crucible Steel Co.; and Mallory Sharon Metals Co. For further information, contact Prof. Harold Margolin, Dept. of Metallurgical Engineering, College of Engineering, New York University, University Heights, New York 53, N. Y.

Engineers

Dr. W. Mayo Smith has been appointed director of research, Escambia Chemical Corp.

James E. Stewart has been named senior chemist, infrared applications, and **Don W. Carle** has been named chief project engineer, gas analyzer section, Scientific Instruments Div., Beckman Instruments, Inc.

Philip Landau has been appointed chief plant chemist, A. C. Horn Co., Div. of Sun Chemical Corp.

Carl Franklin Hoffman, Bethlehem Steel Co., has been chosen by the Penn State Chapter, American Society for Metals, as the 1958 recipient of the David Ford McFarland Award for achievement in metallurgy.

Norman Caplan has been appointed manager, Communications Products Dept., Telecommunications Div., Radio Corp. of America.

Dr. John Mason has been named chief, preliminary design, AiResearch Mfg. Div., Garrett Corp.

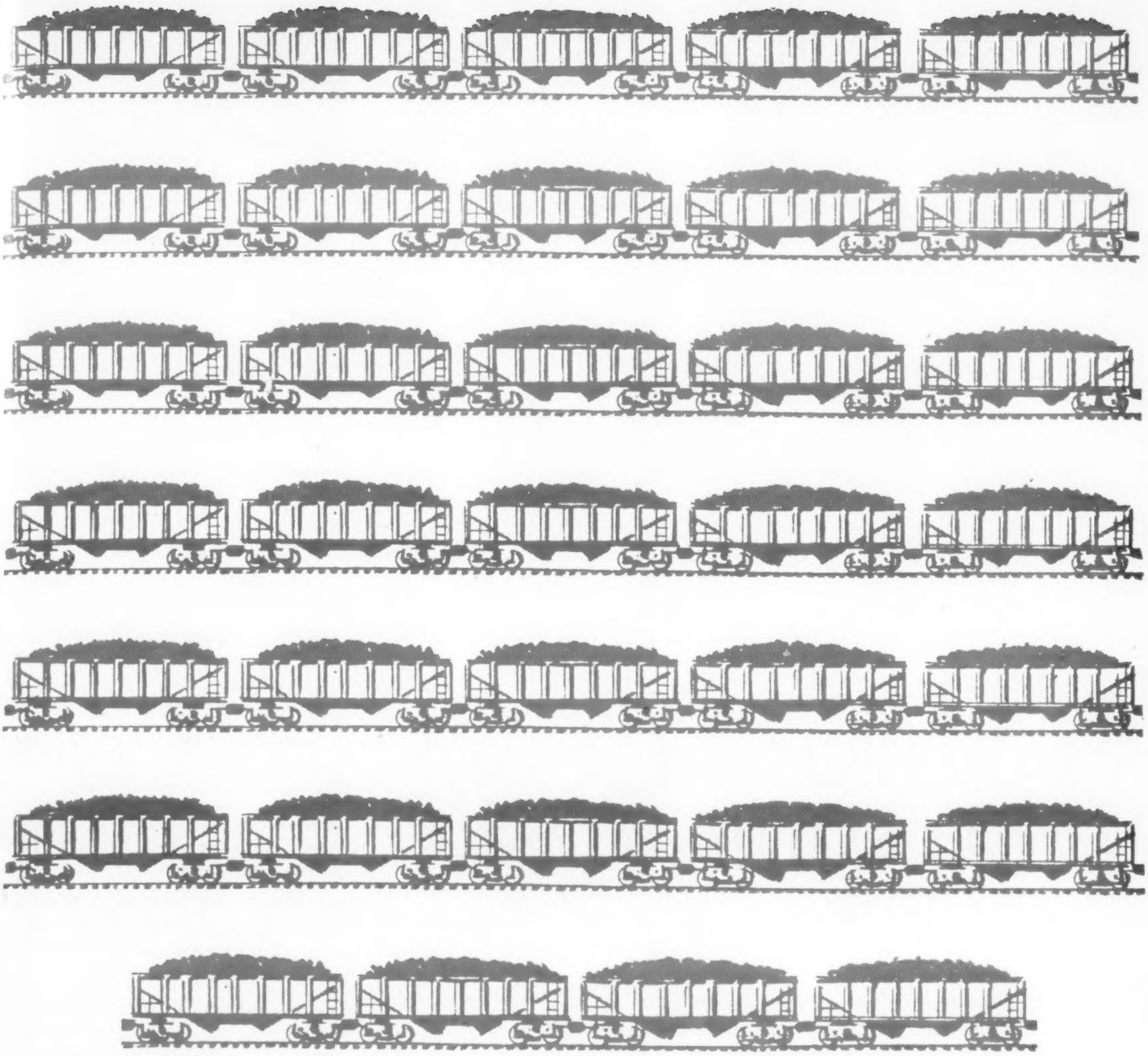
E. E. Saloum has been promoted to chief engineer, Snap-Tite, Inc.

B. E. Petry has been named chief engineer, Oven Div., Baker Perkins Inc.

Dr. Frank P. Florentine has been appointed manager, phenolics engineering unit, Chemical Materials Dept., General Electric Co.

James A. Erdle is now chief engineer, Johnson & Hoffman Mfg. Corp.

R. E. Matzdorff and **C. E. Newberry**, Marquardt Aircraft Co., have been selected to receive the 1957 Manly Memorial Award to be given by the Society of Automotive Engineers for their paper entitled "Requirements,



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News OF INDUSTRY

Parameters, and Design Considerations for Pneumatic Inlet Control Systems."

Dr. Alfred J. Restaino has been named radiation chemist, Chemical Research Dept., Atlas Powder Co.

Bernard Bernstein has been appointed general manager, Advanced Development and Systems Div., Gulton Industries, Inc.

Dr. George E. Ham is now technical director of Spencer Chemical Co.'s Plastics Div.

Companies

Ipsen Ceramics, Inc., a Div. of Ipsen Industries, Inc., has transferred all manufacturing facilities to a new factory in Pecatonica, Ill.

Federal Tool and Mfg. Co. has opened a new short-run stamping plant in North Hollywood, Calif.

Bostitch, Inc. has moved to its new $6 million factory and headquarters in East Greenwich, R. I.

Marbon Chemical Div., Borg Warner Corp., is now operating its new high impact polystyrene plant in Washington, W. Va.

Youngstown Sheet and Tube Co.'s new seamless tube mill in East Chicago, Ind., has begun operations.

Bohn Aluminum & Brass Corp. announces that it has completed its new extruded decorative trim manufacturing facility in Holland, Mich.

Parker Rust Proof Co. announces the opening of a new plant in St. Louis, Mo.

Allis-Chalmers International is the name of a new division of Allis-Chalmers Mfg. Co. The new division will be responsible for all manufacturing, engineering and sales operations outside the U. S. and Canada.

Rust-Oleum Corp. has recently completed a two-year $600,000 plant expansion program.

A. C. Horn Co., Inc., a subsidiary of Sun Chemical Corp., has opened a branch plant in Portland, Ore.

Allison-Campbell Div. is the new name of American Chain & Cable Co.,

NEW FROM DU PONT RESEARCH

Remarkable resistance to ozone, aromatic fuels, and "sour gas" shown by new **FAIRPRENE**® diaphragm material

Now, Du Pont announces the development of a new "Fairprene"† coated fabric for diaphragms. This new material shows remarkable resistance to swelling and deterioration in aromatic fuels, "sour gas" and under high ozone conditions—retains its properties from -65°F.

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Tensile Strength—Lbs./Inch, Min.	75 x 75	80 x 80	300+ x 300+
Tear Strength—Lbs., Trap., Min.	2 x 2	2 x 2	25 x 25
Burst Strength—PSI, Mullens, Min.	125	125	500
Ozone Resistance at 60 Parts Per Million*	OK 208 Hr.	OK 208 Hr.	OK 208 Hr.
Fuel Resistance—Volume Change after 72 Hrs. at Room Temp. in ASTM High Aromatic Fuel**	+3.3%	+9.4%	+20.9%

*Ordinary diaphragm materials fail in 15 minutes under this test.
**Ordinary diaphragm materials swell about 20% under the same conditions.
††The above data are based upon tests on production experience and should not be used as specifications.

†"Fairprene" is Du Pont's registered trademark for its coated fabrics, sheet stocks and cements

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Inc.'s two divisions formerly called **Allison Div.** and **Campbell Machine Div.**

Dictograph Corp. has consolidated all administrative, manufacturing and sales operations into two major divisions: **Acousticon Hearing Aids Div.** and **Dictograph Communications Div.**

Societies

Institute of Printed Circuits, a newly formed association, announces the following officers: president—W. J. McGinley, Methode Mfg. Co.; vice president—A. R. Hughes, Electralab, Inc.; and treasurer—R. L. Swiggett, Photocircuits Corp. Directors are: Karl Clayton, Tingstol Co., and R. G. Zens, Printed Electronics Corp.

American Council of Independent Laboratories, Inc. has elected the following Eastern Div. officers: chairman—Dr. Foster D. Snell, Foster D. Snell, Inc.; vice chairman—Dr. Murray Berdick, Evans Research & Development Corp.; and secretary-treasurer — Robert Stoudt, W. B. Coleman & Co.

Steel Founders' Society of America announces the following 1958-59 officers: president — Ross L. Gilmore, Superior Steel & Malleable Castings Co.; vice president—B. P. Hammond, Blaw-Knox Co.; treasurer — R. G. Parks, National Malleable & Steel Castings Co.; executive vice president—F. Kermit Donaldson; technical and research director—Charles W. Briggs; market development director—George K. Dreher; and assistant secretary—Erwin Dieckmann.

American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., announces the following 1958 officers: president—Dr. Walter R. Hibbard, Jr., General Electric Co.; past president—John C. Kinnear, Jr., Kennecott Copper Corp.; vice president—Dr. John Chipman, Massachusetts Institute of Technology; treasurer—T. D. Jones, American Smelting & Refining Co.; and secretary—Robert W. Shearman. Directors are: H. W. St. Clair, C. C. Long, C. S. Smith, J. B. Austin, J. S. Smart, Jr., K. L. Fetters, H. B. Emerick, K. C. McCutcheon, H. H. Kellogg, W. J. Harris, Jr., and F. M. Hamilton.

(News of Meetings on p 174)

News OF INDUSTRY

Meetings

American Institute of Electrical Engineers, 1958 special technical conference on non-linear magnetics and magnetic amplifiers. Los Angeles. Aug 6-8.

Society of Automotive Engineers, national West Coast meeting. Los Angeles. Aug 11-14.

Conference on Electronic Standards and Measurements, American Institute of Electrical Engineers, Institute of Radio Engineers and National Bureau of Standards. Boulder, Colo. Aug 13-15.

Western Electronic Show and Convention, Wescon. Los Angeles. Aug 19-22.

American Chemical Society, national chemical exposition and conference. Chicago. Sept 7-12.

Society of Automotive Engineers, national farm, construction and industrial machinery meeting, and production forum and display. Milwaukee, Wis. Sept 8-11.

American Die Casting Institute, annual meeting. Chicago. Sept 10-11.

American Rocket Society, Inc., fall meeting. Detroit. Sept 14-18.

Instrument Society of America, 13th annual instrument automation conference and exhibit. Philadelphia. Sept 15-19.

Steel Founders' Society of America, 56th fall meeting. Hot Springs, Va. Sept 22-23.

Iron and Steel Exposition, Assn. of Iron and Steel Engineers. Cleveland. Sept 23-26.

Porcelain Enamel Institute, annual meeting. White Sulphur Springs, W. Va. Sept 25-27.

American Society of Mechanical Engineers, power division conference. Boston. Sept 28-Oct 1.

Electrochemical Society, fall meeting. Ottawa, Ont., Canada. Sept 28-Oct 2.

American Society of Tool Engineers, semi-annual meeting and western tool show. Los Angeles. Sept 29-Oct 3.

Society of Automotive Engineers, national aeronautic meeting, aeronautic production forum and aircraft engineering display. Los Angeles. Sept 29-Oct 3.

Metal Powder Institute, fall meeting. French Lick, Ind. Oct 8-11.

TECHNICAL LITERATURE

(cont'd from p 43)

Books

Designing for Production. *E. N. Baldwin and B. W. Niebel. Richard D. Irwin, Inc., Homewood, Ill., 1957. Cloth, 6 by 9 in., 657 pp. Price $8.40*

A product design is just as much a failure when it cannot be produced at a reasonable cost as it is when the design does not function properly, according to the authors of this design engineering textbook. The two authors—one a manufacturing consultant and the other a professor of industrial engineering—analyze and describe such manufacturing processes as metal forming and shaping, cutting, joining, finishing, inspection, assembly and packaging so that the designer may develop a product around these processes that is functionally sound, marketable and profitable.

The major engineering materials, including ferrous and nonferrous metals, plastics, and natural and synthetic rubber, are described from the product designer's viewpoint.

Polyethylene. *Theodore O. J. Kresser. Reinhold Publishing Corp., New York, 1957. Plastics Applications Series. Cloth, 5 by 7 in., 220 pp. Price $4.95*

Without going into great technical detail, this book shows how polyethylene is produced and how it is made into useful products. Case histories illustrate the use of polyethylene as film, coatings, extrusions, moldings and blown bottles.

HSIC Iron Powder Handbook: Volume I. *Hoeganaes Sponge Iron Corp., Riverton, N. J., 1958. Cloth, 9 by 12 in., 148 pp. Price $36.50*

Described as a "purely technical publication," this book is concerned primarily with the technology of iron powder metallurgy—functionally, it is a reference manual. The full scope of the book is indicated by these typical chapter headings: commercial iron powders; testing methods for iron powders; designing metal powder parts; installations for powder metallurgy; thermal treatment and lubrication of iron powders; basic aspects of sintering; and machining of sintered iron and steel parts.

In order to keep the contents of the book continuously up to date the publishers have chosen to present it in multi-ring binders and to send out new sections as they appear from the printer.

(Reports on p 178)

TECHNICAL LITERATURE

Reports

Copper electrodes SPECIFICATIONS FOR COPPER AND COPPER ALLOY ARC WELDING ELECTRODES. *1957. Available from American Welding Society, 33 W. 39th St., New York 18, N. Y. Price 40¢ (AWS A5.6)*

Chemical composition, mechanical properties and uses for copper-silicon, copper-tin, copper-nickel and copper-aluminum electrodes.

Piezoelectric ceramics COLD-CURED PIEZOELECTRIC CERAMICS. *A. D. Burbage and M. J. Riley, Naval Research Laboratory. Feb '58. 5 pp. Available from Office of Technical Services, Dept. of Commerce, Washington 25, D. C. (NRL 5089)*

Describes a process for the preparation of cold-cured piezoelectric ceramic bodies using commercial grade barium titanate powder with liquid sodium silicate or carnauba wax as binders. The ceramic bodies can be used for detecting sound and mechanical vibration.

Properties of titanium THE PHYSICAL PROPERTIES OF TITANIUM AND TITANIUM ALLOYS. *W. J. Lepkowski and J. W. Holladay, Battelle Memorial Institute. July '57. 87 pp. Available from Office of Technical Services, Dept. of Commerce, Wash. 25, D. C. Price $2.25 (PB 121629)*

Survey of published information on the physical properties of titanium and titanium alloys. This publication is a revision and extension of the Titanium Metallurgical Laboratory's Report No. 39, issued Mar 30, 1956.

Rhenium A SURVEY OF THE LITERATURE ON RHENIUM. *C. T. Sims, E. N. Wyler, G. B. Gaines and D. M. Rosenbaum, Battelle Memorial Institute. June '56. 236 pp. Available from Office of Technical Services, Dept. of Commerce, Washington 25, D. C. Price $4.50 (PB 121826)*

All information accumulated in the literature during the 27 years prior to 1955 is classified into such major fields as the history of rhenium, its occurrence, recovery and production, and its physical, electronic, chemical and metallurgical properties.

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Mr. Prudence Takes the Stand

THE LAST WORD

by H. R. Clauser, Editor

Following is a portion of the transcript of the testimony by Stillmore Prudence, Basket Engineer and Assistant to the Chief Engineer of the Tisket Basket Mfg. Co., given before the Special Subcommitee on Small Oversights.

CHAIRMAN: Mr. Prudence, we welcome you here this morning. I believe you advised me that you would like to make a brief statement before we get on to the questions.

MR. PRUDENCE: Thank you. Mr. Chairman, first I would like to say that I appear here voluntarily and at my own request. I requested to appear in order to clarify fully the questions raised regarding the propriety of my actions in relation to Mr. Hartsell. And second, let me say that the nature of my duties exposes me day in and day out to every conceivable kind of pressure. But in spite of all these outside pressures, let me say that I have not allowed them to influence my objective engineering approach to selecting the best possible materials for my company's products. Mr. Chairman, I am ready now to answer any questions.

CHAIRMAN: Mr. Prudence, I would like to ask you a few questions concerning your letter to me outlining your activities at the convention of the Association of Basket Manufacturers the week of Sept 20, 1955. You stated that you and Mr. Hartsell saw each other several times during that week. Is that correct?

MR. P: Yes, that is correct.

CHAIR: Could you tell us where you saw him?

MR. P: Well, I visited him in his hotel room.

CHAIR: Could you describe the room briefly?

MR. P: As I recollect, it was fairly large—perhaps four to five times as large as this committee room. And I believe it had a bar.

CHAIR: Where else were you, together?

MR. P: I believe we went to a few night clubs together.

CHAIR: And on these occasions, who paid the checks?

MR. P: Well, let me explain that. I did my best on all these occasions to pay my share, because I didn't want to appear to be a free-loader. But Mr. Hartsell always seemed to grab the check ahead of me.

CHAIR: Would you say that engineers, as a group, are free-loaders?

MR. P: Definitely not. I think most engineers will always reach for the check. It just so happens that their reflexes are a little slower than most people's.

CHAIR: Mr. Prudence, you stated in your letter that during that week you also visited with Mr. Hartsell to discuss the performance properties of a new material of theirs. I believe it is called Latem-Citsalp.

MR. P: That is correct.

CHAIR: Where exactly did this visit take place?

MR. P: If I recall correctly, it took place aboard his yacht.

CHAIR: How long did the visit last?

MR. P: Oh, I would say not more than ten or twelve hours.

CHAIR: And how much of that time would you say was spent discussing the . . . uh . . . properties of Latem-Citsalp?

MR. P: Well, as I recall it, Mr. Hartsell gave me a splendid brochure containing all the facts about Latem-Citsalp shortly after I got aboard, so there was really no great need to spend any time on the matter.

CHAIR: When you left, I suppose you took the brochure with you?

MR. P: As a matter of fact, I didn't. I forgot it. But Mr. Hartsell was kind enough to send it to my office.

CHAIR: Now, Mr. Prudence, I believe you said in your letter that you subjected Latem-Citsalp to some very severe tests. I wonder if you could explain to the committee in simple, nontechnical terms these scientific tests.

MR. P: Well, the two most important tests involved checking the resistance of Latem-Citsalp to moisture and abuse.

CHAIR: Don't go into detail, just briefly describe the test equipment.

MR. P: Well, as a matter of fact, we didn't test it on any equipment. Clem, I mean Mr. Hartsell, arranged to have my bathroom and rumpus room papered with Latem-Citsalp so I could test it right at home. We engineers refer to this sort of thing as simulated service testing.

CHAIR: Then, if I understand you correctly, you picked Latem-Citsalp because it was the superior material?

MR. P: That is correct.

CHAIR: I see. I have in my hands, Mr. Prudence, a report from your company's files that states that numerous complaints have been received from customers to the effect that the new Tisket picnic baskets are not ant-proof, as claimed.

MR. P: Yes, I am aware of that report. However, I would like to say that the reported service failures were not the fault of the material. It seems that those complaints were received from people who picnic in areas where the borus-flintus species of ant is prevalent, whereas Latem-Citsalp was developed primarily to repel the gingo species, which is widely prevalent in Madagascar.

CHAIR: Very interesting, Mr. Prudence. Now, Mr. Prudence, I want to be completely fair in my questioning, and I don't want to embarrass you, but wouldn't you say that the fact that Mr. Hartsell treated you so well, might have had something to do with your recommendation to use Latem-Citsalp in the new model of the Tisket picnic basket?

MR. P: No, not at all. I evaluated all the various materials on a strictly scientific basis. It just so happened that Latem-Citsalp came out on top.

CHAIR: But you did admit in your letter, did you not, that your activities with Mr. Hartsell might be subject to misinterpretation by some people?

MR. P: That is correct, and I would like very much to avoid any further criticism of this kind. But I do receive a lot of samples and things from time to time that many people might look upon as gifts. My problem is that I don't know what to do with them.

CHAIR: I see, Mr. Prudence. If you don't mind my suggesting . . .

MR. P: No, not at all.

CHAIR: Well, I might suggest, Mr. Prudence, that you send these so-called gifts to this committee, and we will take care of them. I don't believe I have any further questions. Thank you, Mr. Prudence.